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THE MANUFACTURE AND SALE OF SAINT EINSTEIN

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14 THE PRINCIPLE OF EQUIVALENCE, ETC.

Albert Einstein was fond of propounding thought experiments as if they would somehow account for the research he had never conducted. Einstein also tried to lay claim to well-known experimental facts by propounding that a posteriori *problems were instead* a priori *first principles. He confused induction with deduction and analysis with synthesis. However, even Einstein's thought experiments were unoriginal.*

> "In 1907 Planck broke new ground. It had been established by the careful experiments of R. v. Eötvös that *inertial mass* [***] and *gravitational mass* [***] are always exactly equal [***] Now, said Planck, all energy has inertial properties, and therefore *all energy must gravitate*. Six months later Einstein published a memoir in which he introduced what he later called the *Principle of Equivalence*[.]"—SIR EDMUND WHITTAKER[2844]

14.1 Introduction

Galileo Galilei criticized Aristotle for leaving to logic and assumption that which could be experimentally tested. Albert Einstein became famous for pretending that he had used logic and assumption to create "thought experiments" in lieu of real experiments. In fact, Einstein either copied these thought experiments from his predecessors, or converted the actual experiments others had performed into "thought experiments" so that he could lay claim to them as if he were the first to argue the point. Just as Galileo disproved many of Aristotle's assumptions, many of the fundamental assumptions of the theory of relativity have been physically contradicted.

14.2 Eötvös' Experimental Fact and Planck's Proposition

Maxwell's equations implicitly contain the formula $E = mc^2$. Simon Newcomb pioneered the concept of relativistic energy in 1889.[2845] S. Tolver Preston,[2846] J. J. Thomson,[2847] Henri Poincaré,[2848] Olinto De Pretto,[2849] Fritz Hasenöhrl,[2850] [etc. etc. etc.] each effectively (Albert Einstein, himself, did not expressly state it in 1905), or directly, presented the formula $E = mc^2$, before 1905, and Max Planck[2851] refined the concept in 1906-1908, including Galileo's,[2852] Huyghens',[2853] Newton's,[2854] Boscovich's,[2855] Schopenhauer's,[2856] Mach's,[2857] Bolliger's,[2858] Geissler's,[2859] Bessel's,[2860] Stas',[2861] Eötvös',[2862] Kreichgauer's,[2863] Landolt's,[2864] Heydweiller's[2865] and Hecker's implications that inertial mass and gravitational mass are equivalent—before Albert Einstein.[2866] Einstein was familiar with Henri Poincaré's 1900 paper, which implicitly contained the formula $E = mc^2$, and which presented the thought experiment of synchronizing clocks with light signals that Einstein copied without an attribution.[2867] Einstein also copied Hasenöhrl's thought experiments without an attribution.[2868]

With respect to Planck's equation,[2869] G. N. Lewis gave us relativistic mass in 1908,[2870] and in 1909,

> "drew attention to the formula for the kinetic energy
>
> $$\frac{m_0 c^2}{\left(1 - v^2/c^2\right)^{1/2}} - m_0 c^2$$
>
> and suggested that the last term should be interpreted as the energy of the particle at rest."[2871]

Louis Rougier's *Philosophy and the New Physics*[2872] contains much useful information on this subject. Max Jammer's *Concepts of Mass in Classical and Modern Physics*[2873] is yet more detailed, and Sir Edmund Whittaker's *A History of the Theories of Aether and Electricity* in two volumes is phenomenal.

In 1908, Einstein published a review article on the special theory of relativity. Einstein[2874] cited Planck's earlier 1907 work, which enunciated the principle of equivalence of inertial and gravitational mass. Later, in the same paper, Einstein appears to "nostrify" the principle.

Max Planck wrote on 13 June 1907, before Einstein ever touched upon the subject,

> "An diese Betrachtung schliesst sich sogleich ein drittes Beispiel, nämlich die Frage nach der Identität von träger und ponderabler Masse. Die Wärmestrahlung in einem vollständig evacuirten, von spiegelnden Wänden begrenzten Raume besitzt sicher träge Masse; aber besitzt sie auch ponderable Masse? Wenn diese Frage zu verneinen ist, was wohl das Nächstliegende sein dürfte, so ist damit offenbar die durch alle bisherige Erfahrungen bestätigte und allgemein angenommene Identität von träger und ponderabler Masse aufgehoben. Man darf nicht einwenden, dass die Trägheit der Hohlraumstrahlung unmerklich klein ist gegen die der begrenzenden materiellen Wände. Im Gegentheil: durch ein gehörig grosses Volumen des Hohlraumes lässt sich die Trägheit der Strahlung sogar beliebig gross machen gegen die der Wände. Eine solche, durch dünne starre spiegelnde Wände von dem äusseren Raum vollständig abgeschlossene, im Übrigen frei bewegliche Hohlraumstrahlung liefert ein anschauliches Beispiel eines starren Körpers, dessen Bewegungsgesetze von denen der gewöhnlichen Mechanik total abweichen. Denn während er, äusserlich betrachtet, sich durch Nichts von anderen starren Körpern unterscheidet, auch eine gewisse träge Masse besitzt und dem Gesetz des Beharrungsvermögens gehorcht, ändert sich seine Masse merklich mit der Temperatur, ausserdem hängt sie in bestimmter angebbarer Weise von der Grösse der Geschwindigkeit ab sowie von der Richtung, welche die bewegende Kraft mit der

Geschwindigkeit bildet. Dabei haben die Eigenschaften eines solchen Körpers gar nichts Hypothetisches an sich, sondern lassen sich quantitativ in allen Einzelheiten aus bekannten Gesetzen ableiten.

Angesichts der geschilderten Sachlage, durch welche einige der bisher gewöhnlich als festeste Stütze für theoretische Betrachtungen aller Art benutzten Anschauungen und Sätze ihres allgemeinen Charakters entkleidet werden, muss es als eine Aufgabe von besonderer Wichtigkeit erscheinen, unter den Sätzen, welche bisher der allgemeinen Dynamik zu Grunde gelegt wurden, diejenigen herauszugreifen und besonders in den Vordergrund zu stellen, welche sich auch den Ergebnissen der neuesten Forschungen gegenüber als absolut genau bewährt haben; denn sie allein werden fernerhin Anspruch erheben dürfen, als Fundamente der Dynamik Verwendung zu finden. Damit soll natürlich nicht gesagt werden, dass die oben als merklich unexact gekennzeichneten Sätze künftig ausser Gebrauch zu setzen wären: denn die enorme praktische Bedeutung, welche die Zerlegung der Energie in eine innere und eine fortschreitende, oder die Annahme der absoluten Unveränderlichkeit der Masse, oder die Voraussetzung der Identität der trägen und der ponderablen Masse in der ungeheuren Mehrzahl aller Fälle besitzt, wird ja durch die hier angestellten Betrachtungen überhaupt gar nicht berührt, und niemals wird man in die Lage kommen, auf die Benutzung jener so wesentlich vereinfachenden Annahmen Verzicht leisten zu können. Aber vom Standpunkt der allgemeinen Theorie aus wird man unbedingt und principiell unterscheiden müssen zwischen solchen Sätzen, die nur als Annäherungen aufzufassen sind, und solchen, welche genaue Gültigkeit beanspruchen, schon deshalb, weil heute noch gar nicht abzusehen ist, zu welchen Consequenzen die Weiterentwicklung der exacten Theorie einmal führen wird; sind ja doch häufig genug weitreichende Umwälzungen, auch in der Praxis, von der Entdeckung fast unmerklich kleiner Ungenauigkeiten in einer bis dahin allgemein für exact gehaltenen Theorie ausgegangen.

Fragen wir daher nach den wirklich exacten Grundlagen der allgemeinen Dynamik, so bleibt von allen bekannten Sätzen zunächst nur übrig das P r i n c i p d e r k l e i n s t e n W i r k u n g, welches, wie H. VON HELMHOLTZ [*Footnote:* H. VON HELMHOLTZ, Wissenschaftl. Abhandl. III, S. 203, 1895.] nachgewiesen hat, die Mechanik, die Elektrodynamik und die beiden Hauptsätze der Thermodynamik in ihrer Anwendung auf reversible Processe umfasst. Dass in dem nämlichen Princip auch die Gesetze einer bewegten Hohlraumstrahlung enthalten sind, habe ich im Folgenden (vergl. unten Gl. [12]) besonders gezeigt. Aber das Princip der kleinsten Wirkung genügt noch nicht zur Fundamentirung einer vollständigen Dynamik ponderabler Körper; denn für sich allein gewährt es keinen Ersatz für die oben als unhaltbar nachgewiesene und daher hier nicht einzuführende Zerlegung der Energie eines Körpers in eine fortschreitende und eine innere Energie. Dagegen steht ein solcher Ersatz in vollem Umfang in Aussicht bei der Einführung eines anderen Theorems: des von H. A. LORENTZ [*Footnote:* H. A. LORENTZ, Versl. Kon. Akad. v. Wet., Amsterdam S. 809, 1904.] und in allgemeinster Fassung von A. EINSTEIN [*Footnote:* A. EINSTEIN, Ann. D. Phys. (4) 17, S. 891, 1905.] ausgesprochenen P r i n c i p s d e r R e l a t i v i t ä t. Wenn auch von directen Bestätigungen der Gültigkeit dieses Princips nur eine einzige, allerdings sehr gewichtige, zu nennen ist: das Ergebniss der Versuche von MICHELSON und MORLEY [*Footnote:* A. A. Michelson und E. W. Morley, Amer. Journ. of Science (3) 34, S. 333, 1887.], so ist doch andererseits bis jetzt keine Thatsache bekannt, die es direct hinderte, diesem Princip allgemeine und absolute Genauigkeit zuzuschreiben. Andererseits erweist sich das Princip als so durchgreifend und fruchtbar, dass eine möglichst eingehende Prüfung wünschenswerth erscheint, und diese kann offenbar nur durch Untersuchung der Consequenzen erfolgen, welche es in sich birgt.

Dieser Erwägung folgend hielt ich es für eine lohnende Aufgabe, die Schlüsse zu entwickeln, zu welchen eine Combination des Princips der Relativität mit dem Princip der kleinsten Wirkung für beliebige ponderable Körper führt. Es haben sich dabei gewisse weitere Ausblicke ergeben, sowie auch einige Folgerungen, die vielleicht einer directen experimentellen Prüfung zugänglich sind."[2875]

Though Einstein's 4 December 1907 *Jahrbuch der Radioaktivität und Elektronik* article was meant as a review article of the special theory of relativity, Einstein did not refer to any of Poincaré's many important and relevant works.

Einstein failed to acknowledge that Poincaré had iterated the general principle of relativity, the concept of and exposition on relative simultaneity, the synchronization of clocks by light signals, a generally covariant relativistic theory of gravitation in which gravitational effects propagate at light speed, the group properties of the Lorentz transformation, etc.; before Einstein.[2876]

Einstein again raised the issue of the principle of equivalence in 1911 in a paper he published on the effects of gravity on the propagation of light. Einstein did not mention Planck in this 1911 paper, and Einstein's "nostrification" of the principle of equivalence of inertial and gravitational mass was complete.

14.3 Kinertia's Elevator is Einstein's Happiest Thought

While the principle of equivalence, the excuse given for Einstein's 1911 Newtonian prediction for the deflection of a light ray grazing the Sun, was known before Einstein was born, tales of its practical manifestation were also enunciated before him in thought experiments and real experiments. There was, of course, Jules Verne's famous novel of 1865 *From the Earth to the Moon*.[2877] Then came Kinertia's elevator and train experiments.

In 1919, Einstein promulgated another of his "Eureka!" stories meant to supply a history of his development of an idea, and passed word among reporters that he had been inspired to independently invent the then well-known inertial and gravitational mass equivalence principle,

> "According to tradition, Isaac Newton was led to his theory of gravitation by observing an apple falling from a tree in his garden. The newspaper correspondents start a similar tradition by reporting that Einstein got his theory of gravitation by observing a man falling from the roof of a building in Berlin. Now a man has the advantage of an apple in that he is able to tell his sensations. When Dr. Einstein, who had seen the accident from his library window in the top story of a neighboring apartment house, reached the spot he found the man had hit upon a pile of soft rubbish and had escaped almost without injury. Asked how it felt to fall he told Dr. Einstein that he had no sensation of downward pull at all. This led Dr. Einstein to consider whether the relativity theory, which he had applied only to the case of uniform motion in a straight line, could not be extended to difform or accelerated motion by gravitation. So the special relativity theory which he had enunciated in 1905 developed ten years later into a generalized relativity theory (*Verallgemeinerte Relativitätstheorie*)."[2878]

The New York Times interviewed Albert Einstein and reported on 3 December 1919 that Einstein was,

> "Inspired as Newton was[,] but by the fall of a man from a roof instead of the fall of apple. [***] The doctor lives on the top floor of a fashionable apartment house on one of the few elevated spots in Berlin—so to say, close to the stars which he studies, not with a telescope, but rather with the mental eye, and so far only as they come within the range of his mathematical formulae; for he is not an astronomer but a physicist.
>
> It was from his lofty library, in which this conservation took place, that he observed years ago a man dropping from a neighboring roof—luckily on a pile of soft rubbish—and escaping almost without injury. This man told Dr. Einstein that in falling he experienced no sensation commonly considered as the effect of gravity, which, according to Newton's theory, would pull him down violently toward the earth. This incident, followed by further researches along the same line, started in his mind a complicated chain of thoughts leading finally, as he expressed it, 'not to a disavowal of Newton's theory of gravitation, but to a sublimation or supplement of it. [***] It was during the development of the formulas for difform motions that the incident of the man falling from the roof gave me the idea that gravitation might be explained by difform motion.'"[2879]

Einstein's "Eureka!" story varied and therefore must have been a lie. Einstein stated on 14 December 1922,

> "The breakthrough came suddenly one day. I was sitting on a chair in my patent office in Bern. Suddenly a thought struck me: If a man falls freely, he would not feel his weight, I was taken aback. This simple thought experiment made a deep impression on me. This led me to the theory of gravity."[2880]

In another account written sometime after 22 January 1920, Einstein stated,

> "When I was busy (in 1907) writing a summary of my work on the theory of special relativity [***] I got the happiest thought of my life [***] *for an observer in free-fall from the roof of a house there is during the fall*—at least in his immediate vicinity—*no gravitational field*. Namely, if the observer lets go of any bodies, they remain relative to him, in a state of rest or uniform motion [***] The observer, therefore, is justified in interpreting his state as being 'at rest.'"[2881]

Einstein continues with his story in a fashion that, as Arvid Reuterdahl noted, is remarkably derivative of the "Kinertia" articles, which had appeared years earlier in *Harper's Weekly*.

However, as late as 1916, Einstein had not yet revealed his *happiest thought in life*. Instead, Einstein told another "Kinertia" story in 1916, the elevator analogy,

> "We imagine a large portion of empty space, so far removed from stars and other appreciable masses that we have before us approximately the conditions required by the fundamental law of Galilei. It is then possible to choose a Galileian reference-body for this part of space (world), relative to which points at rest remain at rest and points in motion continue permanently in uniform rectilinear motion. As reference-body let us imagine a spacious chest resembling a room with an observer inside who is equipped with apparatus. Gravitation naturally does not exist for this observer. He must fasten himself with strings to the floor, otherwise the slightest impact against the floor will cause him to rise slowly towards the ceiling of the room.
>
> To the middle of the lid of the chest is fixed externally a hook with rope attached, and now a 'being' (what kind of a being is immaterial to us) begins pulling at this with a constant force. The chest together with the observer then begin to move 'upwards' with a uniformly accelerated motion. In course of time their velocity will reach unheard-of values—provided that we are viewing all this from another reference-body which is not being pulled with a rope.
>
> But how does the man in the chest regard the process? The acceleration of the chest will be transmitted to him by the reaction of the floor of the chest. He must therefore take up this pressure by means of his legs if he does not wish to be laid out full length on the floor. He is then standing in the chest in exactly the same way as anyone stands in a room of a house on our earth. If he release a body which he previously had in his band, the acceleration of the chest will no longer be transmitted to this body, and for this reason the body will approach the floor of the chest with an accelerated relative motion. The observer will further convince himself *that the acceleration of the body towards the floor of the chest is always of the same magnitude, whatever kind of body he may happen to use for the experiment.*
>
> Relying on his knowledge of the gravitational field (as it was discussed

in the preceding section), the man in the chest will thus come to the conclusion that he and the chest are in a gravitational field which is constant with regard to time. Of course he will be puzzled for a moment as to why the chest does not fall in this gravitational field. Just then, however, he discovers the hook in the middle of the lid of the chest and the rope which is attached to it, and he consequently comes to the conclusion that the chest is suspended at rest in the gravitational field.

Ought we to smile at the man and say that he errs in his conclusion? I do not believe we ought to if we wish to remain consistent; we must rather admit that his mode of grasping the situation violates neither reason nor known mechanical laws. Even though it is being accelerated with respect to the 'Galileian space' first considered, we can nevertheless regard the chest as being at rest. We have thus good grounds for extending the principle of relativity to include bodies of reference which are accelerated with respect to each other, and as a result we have gained a powerful argument for a generalised postulate of relativity.

We must note carefully that the possibility of this mode of interpretation rests on the fundamental property of the gravitational field of giving all bodies the same acceleration, or, what comes to the same thing, on the law of the equality of inertial and gravitational mass. If this natural law did not exist, the man in the accelerated chest would not be able to interpret the behaviour of the bodies around him on the supposition of a gravitational field, and he would not be justified on the grounds of experience in supposing his reference-body to be 'at rest.'

Suppose that the man in the chest fixes a rope to the inner side of the lid, and that he attaches a body to the free end of the rope. The result of this will be to stretch the rope so that it will hang 'vertically' downwards. If we ask for an opinion of the cause of tension in the rope, the man in the chest will say: 'The suspended body experiences a downward force in the gravitational field, and this is neutralised by the tension of the rope; what determines the magnitude of the tension of the rope is the *gravitational mass* of the suspended body.' On the other hand, an observer who is poised freely in space will interpret the condition of things thus: 'The rope must perforce take part in the accelerated motion of the chest, and it transmits this motion to the body attached to it. The tension of the rope is just large enough to effect the acceleration of the body. That which determines the magnitude of the tension of the rope is the *inertial mass* of the body.' Guided by this example, we see that our extension of the principle of relativity implies the *necessity* of the law of the equality of inertial and gravitational mass. Thus we have obtained a physical interpretation of this law.

From our consideration of the accelerated chest we see that a general theory of relativity must yield important results on the laws of gravitation. In point of fact, the systematic pursuit of the general idea of relativity has supplied the laws satisfied by the gravitational field. Before proceeding farther, however, I must warn the reader against a misconception suggested

> by these considerations. A gravitational field exists for the man in the chest, despite the fact that there was no such field for the co-ordinate system first chosen. Now we might easily suppose that the existence of a gravitational field is always only an *apparent* one. We might also think that, regardless of the kind of gravitational field which may be present, we could always choose another reference-body such that *no* gravitational field exists with reference to it. This is by no means true for all gravitational fields, but only for those of quite special form. It is, for instance, impossible to choose a body of reference such that, as judged from it, the gravitational field of the earth (in its entirety) vanishes.
>
> We can now appreciate why that argument is not convincing, which we brought forward against the general principle of relativity at the end of Section XVIII. It is certainly true that the observer in the railway carriage experiences a jerk forwards as a result of the application of the brake, and that he recognises in this the non-uniformity of motion (retardation) of the carriage. But he is compelled by nobody to refer this jerk to a 'real' acceleration (retardation) of the carriage. He might also interpret his experience thus: 'My body of reference (the carriage) remains permanently at rest. With reference to it, however, there exists (during the period of application of the brakes) a gravitational field which is directed forwards and which is variable with respect to time. Under the influence of this field, the embankment together with the earth moves non-uniformly in such a manner that their original velocity in the backwards direction is continuously reduced."[2882]

Jules Verne, whose analysis of the problem was not perfect, wrote in 1865 (and we must not forget Galileo) a story of a projectile-ship, fired from a cannon, carrying men to the moon,

> "The president approached the window, and saw a sort of flattened sack floating some yards from the projectile. This object seemed as motionless as the projectile, and was consequently animated with the same ascending movement. [***] 'Because we are floating in space, my dear captain, and in space bodies fall or move (which is the same thing) with equal speed whatever be their weight or form; it is the air, which by its resistance creates these differences in weight. When you create a vacuum in a tube, the objects you send through it, grains of dust or grains of lead, fall with the same rapidity. Here in space is the same cause and the same effect.' [***] In looking through the scuttle Barbicane saw the spectre of the dog, and other divers objects which had been thrown from the projectile, obstinately following them. Diana howled lugubriously on seeing the remains of Satellite, which seemed as motionless as if they reposed on solid earth. [***] Then they struck up a frantic dance, with maniacal gestures, idiotic stampings, and somersaults like those of the boneless clowns in the circus. Diana, joining in the dance, and howling in her turn, jumped to the top of the

> projectile. An unaccountable flapping of wings was then heard amid most fantastic cock-crows, while five or six hens fluttered like bats against the walls. [***] Such was their situation; and Barbicane clearly explained the consequences to his travelling companions, which greatly interested them. But how should they know when the projectile had reached this neutral point situated at that distance, especially when neither themselves, nor the objects enclosed in the projectile, would be any longer subject to the laws of weight?
>
> Up to this time, the travellers, while admitting that this action was constantly decreasing, had not yet become sensible to its total absence.
>
> But that day, about eleven o'clock in the morning, Nicholl having accidentally let a glass slip from his hand, the glass, instead of falling, remained suspended in the air.
>
> 'Ah!' exclaimed Michel Ardan, 'that is rather an amusing piece of natural philosophy.'
>
> And immediately divers other objects, firearms and bottles, abandoned to themselves, held themselves up as by enchantment. Diana too, placed in space by Michel, reproduced, but without any trick, the wonderful suspension practiced by Caston and Robert Houdin. Indeed the dog did not seem to know that she was floating in air.
>
> The three adventurous companions were surprised and stupefied, despite their scientific reasonings. They felt themselves being carried into the domain of wonders! They felt that weight was really wanting to their bodies. If they stretched out their arms, they did not attempt to fall. Their heads shook on their shoulders. Their feet no longer clung to the floor of the projectile. They were like drunken men having no stability in themselves.
>
> Fancy has depicted men without reflection, others without shadow. But here reality, by the neutralisations of attractive forces, produced men in whom nothing had any weight, and who weighed nothing themselves.
>
> Suddenly Michel, taking a spring, left the floor and remained suspended in the air, like Murillo's monk of the Cusine des Anges.
>
> The two friends joined him instantly, and all three formed a miraculous 'Ascension' in the centre of the projectile. [***] A slight side movement brought Michel back toward the padded side; thence he took a bottle and glasses, placed them 'in space' before his companions, and, drinking merrily, they saluted the line with a triple hurrah."

Jules Verne's book was illustrated with images depicting the principle of equivalence. It influenced film pioneer Georges Méliès, whose film *A Trip to the Moon* (*La Voyage dans la Lune*) based on Verne's book appeared in 1902 and was shown around the world. Many of Méliès' films[2883] depict the principle of equivalence, perhaps most notably his *Faust in Hell* (*Faust aux Enfers*) of 1903, and Méliès' *The Merry Frolics of Satan* (*Les Quat' Cents Farces du Diable*) of 1906. These films had little competition and were very popular. It is likely that Einstein had seen them.

Robert Stevenson, a.k.a. "Kinertia", was born in Glasgow in 1844. At age 24, he began to manage the mining interests of Baron Rothschild. In 1882, Stevenson emigrated to the United States and purchased a gold mine in California. He died in New York City, on 2 July 1922, at his residence at 606 West 115th Street; survived by his widow, Georgia Stevenson. In what follows, Stevenson's articles are greatly condensed. All figures have been deleted. The goal here is to record his anticipations of Einstein's thought experiments and the principle of equivalence, with respect to the nature of "weight" and the rejection of the "Newtonian" doctrine of "mutual attraction". Kinertia did *not* present a non-Euclidean geometry to account for the apparent "force" of gravity. Those interested in understanding Kinertia's full theory are encouraged to read his full article. Arvid Reuterdahl informs us that Kinertia filed a description detailing the mechanical workings of Kinertia's "gravity machine" with the Royal Prussian Academy of Sciences on 27 June 1903, which Reuterdahl describes as,

> "The 'gravity machine' of 'Kinertia', when water only is used, generates a spiral vortex in space similar to the vortex of a spiral nebulae. When lead balls are projected from the machine by means of either water or compressed air, then the balls describe elliptical orbits, like the planets, while advancing along the neutral axis of rotation. The resultant path, in the latter case, is therefore an elliptical spiral."[2884]

Reuterdahl believed that Kinertia was the first to present the path of the planets as a corkscrew in space.

"Kinertia" wrote, *inter alia*, in *Harper's Weekly* in 1914,

> "THIS statement is concerning a discovery in natural science, and the ordinary phenomena of daily life, which I discovered about fifteen years ago while engaged in carrying on some experiments to verify what I had previously suspected to be the true physical cause of *Elasticity*, *Gravity*, *Weight* and *Energy*.
>
> While at college in the year 1866, my attention was called by Lord Kelvin to the possibility and importance of the discovery of the true physical cause of Elasticity, and Gravity, which he said for many years engrossed his attention. In his class lectures he devoted much time to the experimental verification of the fundamental principles of the Newtonian system of natural philosophy; and in interpreting an experiment that seemed to establish one of those principles, regarding Newton's theory of force, it struck me that the experiment did not confirm, but rather disproved the action he claimed for it, that in fact his explanation was a misinterpretation of the true action.
>
> As I was too young to challenge his interpretations, I allowed it to remain in abeyance in my mind; and in my practice as an engineer, I often met it as an unsolvable obstacle in many forms of the mechanical application of forces. Theory failed in these particular cases, and empirical formulae were used in text books to meet the requirements of engineering practice.
>
> When I rose in my profession in Great Britain, and was General Manager

of extensive works, I devoted some time to investigating this obscure principle, and corresponded with many of the scientific authorities, such as Kelvin, Tait, and Niven of Cambridge, from 1877 to 1881, but I found that each of them had a different theory of the cause of the discrepancy between theory and practice; and this satisfied me that there was something at the foundation of all natural action which was worth investigating.

Years passed, and through an accident I was deprived of my hearing, causing me to give up my position and go out to California to a rancher's life. There I had a little more leisure, and I worked on this idea until I found it to be the true principle, which as the cause of Elasticity and Gravity, is the fundamental natural cause of all physical phenomena. I found that the fall of bodies is not due to the Newtonian force of attraction inherent in matter.

When I told the scientific authorities this, they seemed to be terribly shocked at such a sacrilegious statement, and many of them thought it was a case for Torquemado to deal with. However, my old professors, Lord Kelvin, and Blackburn, wrote to me that I would first have to prove that Newton's first law of motion was a fallacy, and that Galileo and Newton were fools in believing that they were experimenting with falling bodies at the earth's surface. I did not think the first law was violated, but the more I studied the subject I could see that if the fall of bodies were a reality, as Galileo and Newton believed it to be, it would prove a serious obstacle to the acceptance of my theory.

I set to work to find out by experiment whether bodies actually did fall with the acceleration which the force of attraction was said to produce. Years before that, when in England, where some of our coal mines had vertical shafts about 1500 feet deep, I had studied the cause of weight by having the hoisting engine drop me down with the full acceleration for about 500 feet. Then, by retardation during the lowest 500 feet, I could experience increase of weight all over me so marked that my legs could hardly support me. That taught me that acceleration was the proximate cause of weight, but at the time of these experiments I still thought the acceleration of the falling cage was really caused by the earth's attraction.

In California, while trying to prove that bodies actually fall, as they appear to do, I thought of those experiments and remembered that in the fall down the shaft I did not lose my consciousness. I reasoned that if my body was actually accelerated at a rate of 32 feet per second, I would instantly lose my consciousness, owing to my breath and the light portions of my body not falling as fast as the heavier portion. I read the accounts of parachuters, and bridge jumpers, who declared they were perfectly conscious until the water struck them, and they thought that the water and ground under them was rising towards them. Thus I was led to the conclusion that there was a possibility, after all, Galileo and Newton had been fooled by the apparent fall of bodies, which instead of being a reality, was simply an illusion of the senses, in every way similar to the diurnal revolution of the sun around the earth, which Copernicus proved to be an illusion of the senses.

I wrote to a number of my scientific friends, asking them what they thought of the possibility of falling bodies being an illusion of the senses, but I found that this was the one thing needed to destroy their respect for me. Very few replied, and those who did reply thought I was joking.

After some years of fruitless endeavor to find a crucial experiment that I could present as proof to the scientific authorities, I set to work to study the subject from a mathematical point of view, and in a short time found the conclusive kinematical proof that bodies do not fall. I tried to convince scientists of this fact, but I could not make any impression. They began to think I was a crank.

Now I am retired from business, and will devote the few years of my life in an effort to arouse the public to force scientists to investigate, and either confirm the truth that bodies do not fall or prove that they do fall, as they appear to do and as the universities are teaching all over the world. I hope to find some lover of truth who will back my effort by making a substantial offer to the first scientist who will prove that bodies actually fall with acceleration. Such an offer as that would put the scientific authorities on their mettle, and place them before a world wide audience that will want to know the truth, and it will prevent them from sacrificing any individual professor who dares to teach the unorthodox truth.

The kinematical proof which I am prepared to present gives the *qualitative* analysis of the action, showing how the earth, in its orbital motion round the sun, when combined with its rotations round its axis in the direction of its orbital motion, produces on persons on its surface the illusion that bodies are actually falling of their own gravity to the earth. The proof is of the simplest possible character, and yet so conclusive that any ordinarily educated person can understand it, if he is not controlled by prejudice produced by a life time of training.

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I HAVE set out to prove that the fall of bodies as at present believed and taught, is a pure illusion of the senses, of a character similar to that of the apparent motion of the sun round the earth daily.

The illusion of the sun's motion was believed and taught for twelve hundred years, and it took the combined efforts of Copernicus, Kepler, Galileo, Huygens, Newton, and many other great minds, agitating and demonstrating for more than one hundred and fifty years, to convince the then scientific authorities that the apparent fact was an absurd fallacy.

For fifteen years I have been trying to persuade scientists that the apparent fall of bodies is a similar illusion, and I am met with the same inertia of mind and reluctance to investigate.

The fact that the present doctrine of the fall of bodies has been established and taught as an orthodox truth for nearly two hundred years, is considered by professional scientists as a good reason for their refusal to investigate anything that is contrary to what they believe to be the truth.

The Dean of Science of one of our largest universities told me, in 1903, that if he was known by the University authorities to be investigating this unorthodox doctrine, he would be in danger of losing his professorship at the University. When I asked if he would allow me to demonstrate the truth by an experiment, he said that if it were known to his colleagues that he had so little faith in what he was teaching as to watch an experiment that professed to prove the contrary of what was being taught, he would be jeered at for his credulity. It was the same old story that Doctor Sissi at Padua University told Galileo, when asked to look through the telescope at a new planet. He said that it would be sacrilege for him to do so, since the number 7 is a perfect number, all God's works are perfect, there are 7 planets, and therefore the eighth one seen in the glass is an illusion. [***] The 'Principia' of Newton and the 'Mechanique Celeste' of Laplace are the established authorities on all questions dealing with the motions and configurations of the solar system, as now taught in the universities of the world. But as basis of their mathematical deduction is the apparent fall of bodies, towards the earth, with acceleration.

I shall prove that this apparent fall is a pure illusion of the senses, in every way comparable to the illusion which deceived Ptolemy. We are on the eve of a revolution in physical and astronomical science.

We shall find that weight on the surface of the earth can be produced without attraction;

That the moon is not attracted to the earth, and does not fall with the same acceleration toward the earth, as Newton supposed;

That the tides are not caused by the moon's attraction, but by a peculiar motion of the earth itself;

That the pressure and density of the atmosphere resting on the earth is not caused by its weight due to the earth's attraction:

But that the weight of the atmosphere is caused by the earth's continual pressure against the atmosphere;

That this same pressure (which is intermittent) is the cause of the internal work of the air—a fact which puzzled the mind of the great Langley so long;

That the 'holes in the air' which startle the aviator are due to the same peculiar motion of the earth, where its surface underneath the aviator is not a plain surface but has houses and chasms and trees;

That the same peculiar motion of the earth causes the atmosphere, or air, above a choppy sea, to rock the aeroplane;

That even the Brownian movements, which are thought by some to be the very essence of vitality in organic life, are caused by this same peculiar intermittent pressure of the earth's surface against the inertia of the organized fluid cells within the organism under the pressure of the atmosphere. [***] Ptolemy based his mathematical treatment on the Earth as the fixed centre of the universe.

Newton used the Sun as the fixed centre of coördinates in his mathematical system, and being nearer the truth, he was able to present a much simpler mathematical system than that of Ptolemy.

Now we know that the Sun is not a fixture in the heavens, and consequently to reach a true physical as well as mathematical system of the universe, it is necessary to have fixed coördinates in space, which will enable mathematicians to demonstrate to astronomers the true helicoidal motions and configurations of the planets in fixed space.

The possible motion of the Sun in space, as adrift with the planets, was anticipated by Newton; but his laws of motion prevented him from reaching the true corkscrew path of the planets in space as they revolve round the Sun.

That is the work which is now awaiting the mathematicians of this age, and which will revolutionize the Newtonian System now being taught, even more than that system revolutionized the Ptolemaic System which it supplanted.

Now we have a simple and beautiful mathematical system, from which we can understand the configurations and relative motions of the planets; but, as Newton himself said, there could be no physical cause of these conditions deduced from the mathematical explanation of the phenomena.

Laplace, who stands next to Newton as the greatest exponent of the system, was more daring but less philosophical than Newton. He said the force of attraction which is innate in all matter, and which acts throughout the Universe according to Newton's law of gravitation, is all the physical force which necessary to create and sustain all the phenomena of the Universe. And as he told Napoleon, 'No, Sire, there is no need for any other God but this force of Attraction.'

But now, since it can be proven that there is no such force in the Universe as attraction and that the supposed fall of bodies toward the Earth by that force is only an illusion of the senses, there will be new ground upon which theologians can meet the Laplace attractionists, and Haeckel and his materialists. [***] The very suggestion that modern scientists are teaching to the university students a fallacy has been resented by them to an extent that has prevented me, up to this time, from securing an opportunity to present my proof. Yet the complete and perfect proof of the new theory of Gravitation must, of course, be passed on ultimately by professional scientists, after they have been convinced that the fall of bodies at the earth's surface is an illusion of the senses.

Therefore, what I propose to do in these pages is to show good reasons for believing that what is being taught about the fall of bodies to the students at the universities is an error. I hope that the might of public opinion will force the scientific authorities to investigate this error, and prevent them from sacrificing individual professors who are anxious to study the true theory.

If they cannot force the authorities to investigate, they can at least be challenged to prove that what they are teaching at present about the fall of bodies is a truth.

I have now been fifteen years trying to persuade the scientists of this age to investigate the fact that the Earth falls against bodies with acceleration, instead of the erroneous illusion that bodies fall against the Earth. Though till now it seems that I have made no progress, I feel sure that during the few remaining years of my life I shall, after all, be able at least to set the leaven to working. [***] Thus we hope by ordinary experimental reasoning to be able to prove to the ordinary reader that Newton's cause of gravity is only an imaginary cause, used by him as a 'mathematical metaphor', and that his law is only a law of configuration, not a physical law at all.

As an illustration of what is meant by the difference between a quality and a quantity, and their application in the case of laws and causes, let us take the underground cable car system which Halliday constructed in the city of San Francisco thirty years ago. The cars seemed to run of their own volition, from the bay on the one side of the city to the ocean on the other side. That fact was a source of never ending astonishment to the Chinamen when they first arrived in the city. Here then was a case like that of the Solar System in the days of Galileo, requiring a great philosopher to explain the cause of this most wonderful phenomenon.

LET us suppose that a modern Kepler in charge of the Chabot observatory trained his instruments on these apparently self moving cars, and by reason of his position relative to their lines of motion he found that they described an ellipse in going from the bay to the ocean, and that their angular motion from his position varied inversely as the square of the distance, and that the area described by the radius vector per unit of time was always constant; and, furthermore, that the time taken in making a complete journey to and fro, when squared, was found to be proportionate to the cube of the major axis of the ellipse.

Now with these facts all found by observation, by a careful study of a map of the route, it would be possible to compile a time table that would fix the exact position of the cars every minute of the day, if their motion was uniform, and never interfered with.

That time table would be the *law* of their motion. But the *cause* of their motion would still have to be explained; and here is where the genius of a great philosopher like Newton can attract the admiration of a world.

After a complete study of Kepler's facts, and the rates of acceleration and retardation of the cars as they start from the bay and stop at the ocean and retrace their course without any apparent push or pull, the attention of the scientists is called to the fact that there is water at both termini, which is always in constant flux and reflux, that such an enormous quantity of water in motion to and fro like a pendulum must exert an enormous push and pull on everything that comes within the range of its attraction, which power is just like the power of the magnet in its quality, and is not visible to mortal eyes. Though it is beyond our ken, we must be satisfied to know that this power of attraction is *necessary* to enable us to formulate a mathematical law that will also set at rest the curiosity of the non-scientists who worry so much about causes. [***] In like manner I have been told by these champions of orthodoxy that they would not believe that it is the Earth which falls with acceleration against a falling body, even if I could prove it to be true; that it is an impossibility and an insult to mankind to ask their belief in such a ridiculous supposition.

That being the position that the scientific authorities have assumed towards this great truth for fifteen years, I can only suggest one way to settle this matter, and that is to shame them by the force of public opinion to prove that what they are teaching about the fall of bodies is really true.

I would like to see posted a large monetary prize for the orthodox scientist who can prove that a stone when let go from a height of 16 feet above the surface of the Earth actually falls that distance in space in one second. Lacking this, I can only challenge scientists to give their proof. I will give my proofs in these pages, showing that it is the Earth which falls that 16 feet towards the body or stone in one second of time, and let the readers of this weekly decide who is correct. That appears to me to be a fair way to overcome both inertia and prejudice. As was the custom of the ancient Greeks and Romans, the contest should be in the open forum. There should be no star chamber proceedings in a case, which, when established, will not only free mankind from a ridiculous fallacy, and an illusion of the senses, but will supply a true knowledge of the constitution of the Universe. [***] I remember fifty years ago when I first began to study weight and falling bodies, the impression I got was that weight was an attribute of matter instead of being a mere property, and the consequence was that I believed matter could not exist without weight, nor weight without matter; and it took years of study to get rid of these mistakes, owing to the prejudice they produced on the mind.

Weight, then, is a property of Matter, not an attribute as some scientists believe. Consequently matter can exist constitutionally without weight, and weight can exist without matter, as we know in the case of a hypnotic subject who by suggestion can be made to feel the weight of one hundred pounds, when it only exists as an idea.

The proof that matter can exist without weight depends on the first law of motion; because if a mass moves uniformly in a straight line in space, it cannot have any weight. If weight is caused by the mutual attraction of matter, then a mass subject to attraction must move in a curve. If weight is caused by acceleration, then it cannot follow Newton's laws and move with uniform velocity in a straight line. [***] Perhaps Leonardo da Vinci was the first scientist to record the fact that a ball projected parallel to a horizontal plane offered a different resistance at the start to the same ball thrown vertically upwards with the same velocity. But neither he nor Galileo, nor even Newton, seemed to be fully aware of the dynamical importance of that difference.

The want of a correct knowledge of that fact led to seventy five years' war from Des Cartes to D'Alembert, as to whether a force was proportional to the velocity, or to the square of the velocity.

Newton's definition of mass as the quantity of matter in a body, and proportional to the volume and density conjointly, does not give the dynamical meaning of mass as a component part of the resistance of weight.

Mechanical matter is supposed to be a group, aggregate, or quantum of substance, on which weight has been superimposed by *force*. Newton says, by an innate force; I say, by an applied force; this is the kernel of the whole controversy about gravitation.

Newton's theory is a static theory.

My theory is a kinetic theory of gravitation.

When you hold a weight in your hand you feel a pressure, and it can be proven experimentally that wherever there is weight there is the quality of pressure. Consequently pressure is an attribute of weight; but all pressure is not weight. Therefore weight is not a physical reality; it can be produced and annihilated by force. But if weight were wholly due to attraction, then it could neither be produced nor annihilated by an applied force. Weight is not a kinetic force because it cannot produce acceleration. If a body were accelerated in proportion to its weight, then weight would be a force.

When weight of any magnitude is held in a fixed position 16 feet above the surface of the earth, and let go, it will appear to fall against the surface of the earth in one second of time, and strike with a velocity of 32 feet per second; consequently the acceleration is said to be 32 feet per second, per second.

But if it can be shown that the earth in its curvilinear motion rushes up against the body with that acceleration, then it is unnecessary to adopt the Newtonian theory of attraction to explain the apparent fall of bodies.

Figure 2 gives a kinetic illustration, showing how the Earth in its orbit, without rotation, falls against the body, with the acceleration of gravity, in one second, when the body is held at a height of 16 feet above the surface and let go, so that it is free from the earth's orbital motion; and, according to the Lex I of Newton, the body moves with uniform velocity in the straight line PP' in space, until the earth's acceleration in its orbital curve brings the earth up against the body with a differential velocity 32 feet per second in one second of time from when the body at P is released. [***] Now just think of dear old Galileo dropping different weights from 1 pound to 100 pounds from the top of the tower of Pisa, to prove to the Pope and his Cardinals that Aristotle was wrong in saying that the heavier weight fell the faster, and these celebrities standing amazed with their mouths wide open at the spectacle, which proved Aristotle to be a false guide for the Church, when in reality the weights were not falling at all. And just think of Newton being knighted, and idolized by the Royal Society and all the rest of the world for nearly two centuries, for proving by mathematical reasoning that the fall and acceleration of the body is caused by the attraction of the earth.

Yet the truth will establish itself and then the world will smile at the present day fallacy that is being taught; and especially when it reads in the writings of great philosophers such adoration of Newton's law of gravitation.

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I SHALL now quote in condensed form the opinions of a few of the great philosophers and scientists who have since the days of Newton studied this subject of attraction—in order to show that I am fully warranted in challenging the doctrine of orthodox science regarding the existence, nature, cause, and laws of this idol, this unknown God, they have so long worshipped. These quotations show that this theory of attraction has always been looked upon by great and independent thinkers as a bogus theory; and when I complete the proof that bodies do not fall—that will be proof positive that they cannot be under the influence of the Earth's attraction. And when I prove to the scientists what Kinertia in its nature, cause, and laws really is, then it will be seen that the Sun does not attract the planets and that the force of gravitation is not of an attractive character at all.

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I HAVE shown the absurdity of attraction from various dynamical standpoints, and I have shown that many of the greatest natural philosophers during the last two hundred years, including Newton himself, could not be brought to believe that attraction was a physical quality; but held that it was only useful as a mathematical metaphor, to give to the law of the distance a comprehensive form. [***] According to the present erroneous doctrine, Gravity and Weight are produced throughout the Universe by the mutual attraction of one particle for another, in the manner mentioned in Newton's law of Gravitation. See the text books and encyclopedias on Gravity and Weight. I will now show by the following proposition that the above theory is an absurd fallacy.

Prop. I—*To prove that Gravity and Weight can be produced by man's power and intelligence combined, without the mutual attraction of matter*.

In Fig. 1 let $XX'YY'$ be a fixed coordinate system in the plane of the paper. Let A, B, C, be a ball of any mass M (without weight), gyrating in a circle in free space, with any uniform velocity V, without rotation, and with radius R from the centre of the circle to the centre of the mass of the ball. Let $2r = 1$ mile $=$ diameter of ball; then any particle P on the surface of the ball would be pressed towards the centre of the ball, with the same physical quality as that which gravity and weight are supposed to produce. Now to cause a mass to gyrate in a circle requires not only power, but also some Intelligence to direct the power in its application.

If R = 53,200 miles, V = 18 miles per second of time.

The pressure of P on the surface of the ball towards its centre would be M 32 = mg = Weight at the Earth's surface, where M = mass of Particle P. (See textbooks, both qualitative and qualitative treatment.) See Newton's rule of reason, in Article V, which shows that if gravity and weight can be produced so easily as by this experiment, then there is not need for the Newtonian force of attraction.

I am only dealing with weight as a physical quality due to pressure. There is no need to ask what happens on the other side of the ball, because if the ball were sliding along a rigid circle of radius R + r, the same weight pressure would be there also.

Further Kinetic Illustration

Fig. 2. I use these car illustrations so that the reader may imagine himself as a passenger and actually experiencing the pressure and weight due to the gyration of the car in its circle, and so be convinced of the absurdity of the theory of attraction.

Let C be an imponderable car of mass M, gyrating in a circle of radius R = 53,200 miles, with uniform velocity of V = 18 miles per second, in free space, fixed and infinite; without any other material body in the same space to which it could bear any space or time relationship; taking the plane of the paper for the plane of the motion, and looking down from above. Then its motion in fixed space would be absolute, and its momentum absolute, its acceleration absolute, and its mass absolute. Suppose it to be inhabited like the earth by intelligent beings whose minds during ten thousand generations had been gradually developed to a point when they began to study the nature, cause, and laws of the phenomena that affected their senses within the car. This motion V, going on from generation to generation, without any visible point of reference, would be unknowable to the inhabitants; but there would be several facts within the car which would be knowable and likely to excite their curiosity and wonder.

First, every loose thing, and every person within the car, would be apparently pulled by some invisible force towards one side of the car; and those with the best gift of forming hypotheses on the subject would be called at first philosophers, because they would base their theories on the laws of thought, and deduce by geometrical and logical reasoning many wonderful results. They would believe, of course, the car to be absolutely at rest in space. Then after ages of speculation on the *what*, and the *why*, of this phenomena, a period would arrive when these metaphysicians would become more practical and would say as Galileo said, ‘Why bother about the nature and cause of the phenomena?’ (See Dialogue 202.) ‘Let us experiment and find its laws, or what is called the *how* of the performance’, as Lord Verulam [Francis Bacon] in his *Novum Organum* recommended. This inductive method of research was the genetic starting point of what is now called Science, and its professors are now called Scientists, instead of Philosophers. The scope of the study has been narrowed, but the results have increased beyond all comparison.

Aristotle (the master of those who know) explained that weight was caused by the tendency of material bodies to return to their proper place in nature, and that tendency caused them to fall towards the side of the car, from which it took an effort to lift them; and that the rate of fall was proportional to their weight.

Epicurus, on the other hand, compared the tendency of a body to fall to the tendency he felt when hungry and passing a restaurant where a savory stew was being cooked. He said it was a case of appetite or desire, and that a physical quality or substance was naturally endowed with physical desire, as the physiological quality had the craving for food, and the spiritual for truth.

The theologians for fifteen hundred years preferred the explanation of Aristotle, until a great experimental philosopher called Galileo began to investigate the subject. He said, Why bother about causes? Let us find the laws of falling bodies first, and by that means we can better arrive at a knowledge of causation. (See Dialogue 202.) He lifted bodies of various sizes, densities, and weights, to great distances from the side of the car, and let them fall back of their own volition; and by careful measurements with pendulums and clepsydrias he established the laws of their motion, on the supposition that the car was at rest, and the motion was all in the apparently falling body.

Then he projected them parallel to the sides, and at various distances with various velocities, and found the trajectory to be a parabola, and he found numerous other facts, all of which you can find in his dialogues already mentioned. When he was threatened by the Inquisition, he took up the speculative study of the causes; and in his other great work on the system of the world he showed that he was nearer to the truth than either Kepler, Descartes, or Newton, but the infirmities of age prevented him from completing the task.

Newton, another great philosopher, was born the same year that Galileo died; and in his youth was trained in Galileo's system by the greatest mathematician of that age, Doctor Barrow of Cambridge. He became interested in the fall of bodies, and by using established facts which Kepler had deduced from Tycho Brache's observations, he formulated a geometrical law of motion, which if the car had been stationary, or moving in a straight line in space, as Newton supposed, would have been as marvellous as true. So wonderfully correct was this law in its geometrical application that it seemed to hypnotize with its brilliancy all the scientist of the world for two hundred years. He actually made them believe that the weight and fall were caused by the mutual attraction between the mass of the apparently falling bodies and the mass of the car, all concentrated in the side of the car; that it did not matter whether the car was absolutely at rest or moving with any finite velocity in space; that the cause of the weight and rate of acceleration, or fall of bodies towards the side of the car, depended on the mutual innate desire they had to pull each other; and that the relative resultant pull was always equal to $Mm \div D^2$, where M = mass of car, and m = mass of body, and D = distance from the side of the car to the centre of the body; and that it did not depend on the velocity at all. And beyond this point no human research has been able to penetrate. You will notice that this is a mathematical resultant, not a natural or physical resultant, because physically, Nature in producing an aggregate resultant mass always adds its masses, but by this law they are multiplied to meet the mathematical requirements of the case.

> Anyone acquainted with Dynamics, or Mechanics, will see at a glance that weight can be produced in the way shown in these diagrams without any innate force of attraction in matter, and as astronomical dynamics is only a special application of the general laws of mechanics, you will wonder why science should have been so long hypnotized with such an absurd fallacy as this Newtonian doctrine of attraction."[2885]

Of course, Galileo Galilei is famous for dropping balls from the leaning tower of Pisa and is the ultimate source of the principle of equivalence. Einstein was quoted in *The New York Times*, on 3 April 1921, on the front page:

> "The interview took place in the Captain's cabin, where Professor Einstein was almost surrounded by speakers after knowledge.
>
> 'It is a theory of space and time, so far as physics are concerned,' he said.
>
> 'How long did it take you to conceive your theory?' he was asked.
>
> 'I have not finished yet,' he said with a laugh. 'But I have worked on it for about sixteen years. The theory consists of two grades or steps. On one I have been working for about six years and on the other about eight or nine years.
>
> 'I first became interested in it through the question of the distribution and expansion of light in space; that is, for the first grade or step. The fact that an iron ball and a wooden ball fall to the ground at the same speed was perhaps the reason which prompted me to take the second step.'"

Albert Einstein stated in 1921,

> "Two of the great facts explained by the theory are the relativity of motion and the equivalence of mass of inertia and mass of weight, said Prof. Einstein.
>
> 'There has been a false opinion widely spread among the general public,' [Einstein] said, 'that the theory of relativity is to be taken as differing radically from the previous developments in physics from the time of Galileo and Newton—that it is violently opposed to their deductions. The contrary is true. Without the discoveries of every one of the great men of physics, those who laid down preceding laws, relativity would have been impossible to conceive and there would have been no basis for it. Psychologically, it is impossible to come to such a theory at once without the work which must be done before. The four men who laid the foundations of physics on which I have been able to construct my theory are Galileo, Newton, Maxwell, and Lorenz.'"[2886]

Philipp Frank gave a lecture in 1909, which presented thought experiments pertaining to the principle of equivalence Einstein would essentially later repeat,[2887]

> "The system of the fixed stars constitutes a fundamental body. Even in

shooting a cannon ball towards the south we see no deviation from the law of inertia if we consider it with reference to the fixed stars. The ball remains in the same plane; but this plane does not retain the same relative position to the meridian of the earth, wherefore, of course, with reference to the earth the law of inertia is violated. On the whole it is evident that we really recover all the observed motor phenomena when we refer Newton's laws of motion to the fixed stars. Not until they are referred to the fixed stars do these laws acquire an exact sense which makes it possible to apply them to concrete conditions.

We shall call those motions which are referred to a fundamental body 'true movements' and those related to any other body of reference 'apparent movements.' For instance the immobility of my chair is only apparent, for when referred to the fixed stars it is in motion.

We now ask whether there are any other fundamental bodies aside from the system of the fixed stars. Obviously not any body revolving in an opposite direction to the fixed stars can be such a fundamental body, for considered with reference to such a body all rectilinear movements are curved. Therefore the law of inertia could not hold with reference to the body in question if it is valid with reference to the fixed stars. Then too a fundamental body can possess no acceleration with reference to the fixed stars, because otherwise there would be no uniformity of the motion of inertia with reference to it. However, these conditions are not only necessary but they are sufficient to characterize a fundamental body. All bodies moving uniformly and in a straight line with reference to the fixed stars will also be fundamental bodies inasmuch as rectilinearity and uniformity continue to hold for them, as do likewise the supplementary velocities determined by the second law. Accordingly Newton's laws do not indicate one single fundamental body, but an infinite number moving in opposite directions with a uniform and rectilinear motion.

Hence we may well speak of 'true' in contrast to apparent rotary motion; for all bodies revolving with reference to a fundamental body revolve with reference to all other bodies. The same is true of true acceleration because an acceleration with respect to a fundamental body is also acceleration (i. e., change of velocity) with respect to all the rest. On the other hand, there is no sense in speaking of 'true' uniform rectilinear motion; for if a body possesses a uniform velocity with respect to the fixed stars, it is itself a fundamental body possessing of course with respect to itself a velocity of zero; it is at rest.

Accordingly there is true acceleration, but not true velocity. From this is easily derived a proposition established by Newton which is called the principle of relativity of mechanics, namely that a uniform rectilinear movement of the system as a whole makes no change in the processes within the system; that is to say, we can not tell from the processes within the system what velocity the uniform rectilinear movement possesses with reference to the fixed stars. On the other hand, the rotary motion of a system has indeed an influence on the processes within the system, as for instance in the phenomena of centrifugal force; thus the earth has become flattened at its poles because of its rotation, or if I revolve a dish full of water the water will rise at the sides.

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Is it to a certain extent accidental, or is it essential, that the totality of the fixed stars coincides with that fundamental body in relation to which the laws of Newton hold valid? Or to put it more clearly: If the fixed stars were set violently in motion among each other and hence could no longer constitute a fixed body of reference, would the mechanical processes on earth proceed exactly as they did before? For instance, would the Foucault pendulum move just as at present, even though it now turns with the fixed stars, whereas in that case it would not be quite clear which constellation's revolution it should join?

Were everything to remain as of old the fundamental system of reference would not be determined by the fixed stars but would only accidentally coincide with them, and would in reality be some merely ideal or yet undiscovered body. In the other case all mechanical occurrences on earth would have to be completely altered to correspond with the promiscuous movements of the fixed stars.

It is well known that this is the view held by Ernst Mach. It alone holds with consistent firmness to physical relativism, and it alone answers the second main question of physics in the relativistic sense.

The opposite view is represented by Alois Höfler in his studies on the current philosophy of mechanics, and lately by G. Hamel, professor of mechanics at the technical high school of Brünn, in an essay which appeared in the annual report of the German mathematical society of 1909 on 'Space, Time and Energy as a priori Forms of Thought.'

Before I enter upon the controversy itself I would like further to elucidate Mach's view by carrying out its results somewhat farther. In his well-known essay on the *History and Root of the Principle of the Conservation of Energy* Mach ascribes to the distant masses in space a direct influence on the motor phenomena of the earth which supplements the influence afforded by gravitation. Of course no effect of gravitation from the fixed stars upon the earth can be observed, yet in spite of this they influence, for instance, the plane of oscillation of the Foucault pendulum because in Mach's opinion it remains parallel to them.

The question now arises according to what general law of nature this influence operates which does not, like gravity, produce accelerations but velocities instead. Obviously this influence must be a property belonging to every mass, for according to our present conception the fixed stars of course are precisely the same sort of masses as earthly bodies.

However, experience teaches us that terrestrial masses have no more influence on the plane of oscillation of the Foucault pendulum than has the changing position of the moon, sun and planets; but on the other hand it is exactly the most distant masses, the fixed stars, which determine its plane of oscillation. Accordingly we must either assume that the effect is directly proportional to the distance of the masses (which would be very strange indeed) or simply assume that this effect is proportional to the effective masses and independent of the distance, whence the dominant influence of the more remote, as the far greater and more numerous, bodies would naturally follow, and Mach inclines to this latter view.

Mach's view shows most clearly in his position with regard to Newton's famous bucket experiment. In this Newton intended to show that the centrifugal force produced by a revolving body is due not to its relative but to its absolute velocity of rotation. He suspended a bucket filled with water by a vertical cord, twisted the cord quite tightly and then let it untwist itself, in this way setting the bucket to revolve rapidly. At first the water did not rotate with the bucket and therefore the bucket had a velocity of rotation with reference to the water while in the meantime the surface of the water remained undisturbed. In time, however, friction caused the water to become so affected by the rotary motion that bucket and water revolved like one homogeneous mass whereby the centrifugal force caused the water to rise at the sides of the bucket and the surface became concave.

Hence it is evident that the centrifugal force reached its greatest strength at the moment when the relative motion of the water with respect to the bucket became zero; hence according to Newton this force can be produced only by the absolute rotary motion of the water.

To this now Mach justly protests that only the relative rotation of the water with reference to the fixed stars is to be considered, for this system of the fixed stars and not the bucket is the fundamental body. And indeed at first the water was at rest with reference to the fixed stars, but at the close of the experiment it was revolving. The mass of the bucket compared to the mass of the fixed stars is an entirely negligible quantity, so that it does not depend in the least upon the rotation. But we can not know, adds Mach, how the experiment would turn out if the sides of the bucket were miles thick; and by this he apparently means so thick that their mass would be considerable even when compared with the mass of the system of fixed stars. Then indeed might the rotation of the bucket disturb the action of the fixed stars.

Höfler protests, on the other hand, that a system which is symmetrical round its axis could not according to all our experience in mechanics produce by its rotation that sort of an effect on the water within it.

This also is quite true. But the effect of the masses assumed by Mach is such that it can not be expressed in our ordinary experiences with mechanics except by means of the facts of the inertia of all motion with reference to the fixed stars. New conditions such as the rotation of an enormously thick bucket might give rise to new phenomena. If we agree with Mach's view that the rotation of the plane of the Foucault pendulum is directly produced by the masses of the fixed stars, we must likewise admit, in order to be consistent, that the relative rotation of the very thick bucket might give rise to similar effects with reference to the water, as the rotation of the system of the fixed stars with reference to the earth to the plane of oscillation.

Höfler expresses his contention against Mach's thesis in the form of the following question: If in Galileo's time the sky had been clouded over and had never become clear again so that we would never have been able to have taken the stars into our calculation, would it then have been impossible to have established our present mechanics solely by the aid of terrestrial experiments? By this question Höfler means to say that if the connection with the fixed stars were a constituent of the concept of uniform motion, we would never have been able in such an overclouded world to have established the law of inertia, for instance, whereas in reality it is clear that this would nevertheless have been possible.

I will not dwell on the more psychological question as to whether or how easily this would have been possible, but will only consider now the logical construction of mechanics in such a darkened world on the hypothesis that easily or with difficulty in one way or another we would have attained to our present knowledge of mechanics.

Let us for a moment imagine ourselves in such a world. Above our heads extends a uniform vault of uninterrupted gray or black. Were we to shoot projectiles toward the south we would see that they describe paths which are curved towards the west; if we started pendulums to vibrating we would see that they would revolve their planes of oscillation in mysterious periods—I say mysterious because we might perhaps be able to perceive the change of day and night as an alternation of light and darkness, but would not be able to refer it to the movements of celestial bodies. Perhaps at first we would surmise that the motion of the pendulum could be ascribed to optical influences. I would like to see placed in such a world one of the philosophers who regard the law of inertia as an *a priori* truth. In the face of these mysterious curvatures and deflections he would probably find no adherents and he would not know himself what to make of his own standpoint.

Finally, let us assume, there arises a dauntless man, the Copernicus of this starless world, who says that all motions proceed spontaneously in a straight line, but that this straight line is not straight with reference to the earth but with respect to a purely ideal system of reference which turns in a direction opposite to that of the earth. The period of this rotation is supplied by the period of the Foucault pendulum.

This man would of course deny physical relativism upon the earth, for in his opinion terrestrial processes would not depend only on the relative velocities of terrestrial bodies but on something else besides, viz., their velocities with respect to a purely ideal system of reference. Nevertheless, he would not introduce any non-physical element because for the purpose of the physicist a purely ideal system of reference whose motion with respect to an empirical system is known serves the same purpose as would the empirical system itself. This bold innovator might finally refer the words 'true rest' and 'true motion' to his ideal fundamental body and so ascribe true motion and only apparent rest to the earth, thus maintaining a mechanics which would coincide literally with that of ours to-day, except that no small luminous points would be seen sparkling in connection with the fundamental body.

Hence we see that physical relativism is not a necessary tool of the physicist. Apart, perhaps, from the psychological improbability—of which, however, nothing more positive can be said—the possibility of the development here indicated is logically free from objections throughout, and, therefore the same is also true of the possibility of a nonrelativistic physics.

But I would like to strengthen the argument of Höfler even somewhat further. That is to say, I would ask whether the world in which we live is then really so essentially different from that fictitious one. Imagine the dark roof which conceals the sky placed somewhat higher so that there is room beneath it for the fixed stars, perhaps as the dark background which may be seen nightly in the starry sky. The whole difference then consists in the fact that not only the Foucault pendulum and similar appliances move with reference to the earth, but enormously greater masses as well—all the twinkling lights of the sky by which the thought of a fundamental body in motion with respect to the earth is psychologically greatly facilitated, but logically is not much changed. Now imagine the sky of this earlier dark world suddenly illuminated; then we would see that the fictitious system of reference is closely linked to enormous cosmic masses, and it would be easy enough to accept Mach's hypothesis that these masses condition the fundamental system. . . .

If a distinction must be drawn between the respective values of the conceptions of Mach and Höfler, it is as follows: Mach's view adds decidedly more to the observed facts; for that it retains physical relativism does not involve freedom from hypothesis, because at best this relativism is theory and not fact. Mach sets up, hypothetically of course, a new formal natural law with regard to the action of masses existing side by side with gravitation, affecting the experiment very materially but unable to raise any claim to the simplest description of actual conditions.

The other view, which simply introduces the system of reference procured by observation of the terrestrial and celestial movements without asking whence all this is derived, represents the present state of our knowledge most adequately without any arbitrary addendum but also without giving the spirit of inquiry any incentive to new experiments.

It is the old contrast between the most exact and least hypothetical representation possible of the known science, and progressive inquiry after new things in more or less daring and fantastic hypotheses. But Mach in this case stands in the opposite camp as in most other cases where his repugnance to all hypothesis has made him a pioneer in the phenomenological direction. . . .

I therefore believe I have proved that we can grant the following: Physical phenomena do not depend only on the relative motion of bodies without at the same time admitting the possibility of the concept of an absolute motion in the philosophical sense."[2888]

"Mach's" principle fails for many reasons. It depends upon the mystical notion of *instantaneous* "action at a distance", *i.e.* mutual attraction, and it does not tell us what general laws dictate that the fixed stars be fixed, which laws are more fundamental than Mach's fundamental assertions. Frank sought to provide an answer, as did Newton with absolute space, and many others with the æther hypothesis. Other possibilities certainly exist, though the minute expanse of the visible universe leaves us guessing.

14.4 Dynamism

Long before Einstein was born, Roger Joseph Boscovich introduced a theory of Dynamism. Boscovich argued in the 1700's for a general principle of relativity, length contraction, time dilatation, "Mach's principle" and the notion that "atoms" are point centers of force.[2889]

Boscovich wrote in 1763 in the second supplement to his *Natural Philosophy,*

> "§ II
>
> *Of Space & Time, as we know them*
>
> {We cannot obtain an absolute knowledge of local modes of existence nor yet of absolute distances or magnitudes. [The original margin notes are here reproduced inside of braces {}.]}
>
> 18. We have spoken, in the preceding Supplement, of Space & Time, as they are in themselves; it remains for us to say a few words on matters that pertain to them, in so far as they come within our knowledge. We can in no direct way obtain a knowledge through the senses of those real modes of existence, nor can we discern one of them from another. We do indeed perceive, by a difference of ideas excited in the mind by means of the senses, a determinate relation of distance & position, such as arises from any two local modes of existence; but the same idea may be produced by innumerable pairs of modes or real points of position; these induce the relations of equal distances & like positions, both amongst themselves & with regard to our organs, & to the rest of the circumjacent bodies. For, two points of matter, which anywhere have a given distance & position induced by some two modes of existence, may somewhere else on account of two other modes of existence have a relation of equal distance & like position, for instance if the distances exist parallel to one another. If those points, we, & all the circumjacent bodies change their real positions, & yet do so in such a manner that all the distances remain equal & parallel to what they were at the start, we shall get exactly the same ideas. Nay, we shall get the same ideas, if, while the magnitudes of the distances remain the same, all their directions are turned through any the same angle, & thus make the same angles with one another as before. Even if all these distances were diminished, while the angles remained constant, & the ratio of the distances to one another also remained constant, but the forces did not change owing to that change of distance; then if the scale of forces is correctly altered, that is to say, that

curved line, whose ordinates express the forces; then there would be no change in our ideas.

> {The motion, if any, common to us & the Universe could not come within our knowledge; nor could we know it, if it were increased in any ratio, or diminished, as a whole.}

19. Hence it follows that, if the whole Universe within our sight were moved by a parallel motion in any direction, & at the same time rotated through any angle, we could never be aware of the motion or the rotation. Similarly, if the whole region containing the room in which we are, the plains & the hills, were simultaneously turned round by some approximately common motion of the Earth, we should not be aware of such a motion; for practically the same ideas would be excited in the mind. Moreover, it might be the case that the whole Universe within our sight should daily contract or expand, while the scale of forces contracted or expanded in the same ratio; if such a thing did happen, there would be no change of ideas in our mind, & so we should have no feeling that such a change was taking place.

> {Since, if our position & that of everything we see is changed, our ideas are not changed; therefore we can ascribe no motion to ourselves or to anything else.}

20. When either objects external to us, or our organs change their modes of existence in such a way that that first equality or similitude does not remain constant, then indeed the ideas are altered, & there is a feeling of change; but the ideas are the same exactly, whether the external objects suffer the change, or our organs, or both of them unequally. In every case our ideas refer to the difference between the new state & the old, & not to the absolute change, which does not come within the scope of our senses. Thus, whether the stars move round the Earth, or the Earth & ourselves move in the opposite direction round them, the ideas are the same, & there is the same sensation. We can never perceive absolute changes; we can only perceive the difference from the former configuration that has arisen. Further, when there is nothing at hand to warn us as to the change of our organs, then indeed we shall count ourselves to have been unmoved, owing to a general prejudice for counting as nothing those things that are nothing in our mind; for we cannot know of this change, & we attribute the whole of the change to objects situated outside of ourselves. In such manner any one would be mistaken in thinking, when on board ship, that he himself was motionless, while the shore, the hills & even the sea were in motion.

> {The manner in which we are to judge of the equality of two things from their equality with a third; there never can be congruence in length, any more than there can be in time; the matter is to be inferred from causes.}

21. Again, it is to be observed first of all that from this principle of the [invariance] of those things, of which we cannot perceive the change through our senses, there comes forth the method that we use for comparing the magnitudes of intervals with one another; here, that, which is taken as a

measure, is assumed to be [invariant]. Also we make use of the axiom, *things that are equal to the same thing are equal to one another*; & from this is deduced another one pertaining to the same thing, namely, *things that are equal multiples, or submultiples, of each, are also equal to one another*; & also this, *things that coincide are equal*. We take a wooden or iron ten-foot rod; & if we find that this is congruent with one given interval when applied to it either once or a hundred times, & also congruent to another interval when applied to it either once or a hundred times, then we say that these intervals are equal. Further, we consider the wooden or iron ten-foot rod to be the same standard of comparison after translation. Now, if it consisted of perfectly continuous & solid matter, we might hold it to be exactly the same standard of comparison; but in my theory of points at a distance from one another, all the points of the ten-foot rod, while they are being transferred, really change the distance continually. For the distance is constituted by those real modes of existence, & these are continually changing. But if they are changed in such a manner that the modes which follow establish real relations of equal distances, the standard of comparison will not be identically the same; & yet it will still be an equal one, & the equality of the measured intervals will be correctly determined. We can no more transfer the length of the ten-foot rod, constituted in its first position by the first real modes, to the place of the length constituted in its second position by the second real modes, than we are able to do so for intervals themselves, which we compare by measurement. But, because we perceive none of this change during the translation, such as may demonstrate to us a relation of length, therefore we take that length to be the same. But really in this translation it will always suffer some slight change. It might happen that it underwent even some very great change, common to it & our senses, so that we should not perceive the change; & that, when restored to its former position, it would return to a state equal & similar to that which it had at first. However, there always is some slight change, owing to the fact that the forces which connect the points of matter, will be changed to some slight extent, if its position is altered with respect to all the rest of the Universe. Indeed, the same is the case in the ordinary theory. For no body is quite without little spaces interspersed within it, altogether incapable of being compressed or dilated; & this dilatation & compression undoubtedly occurs in every case of translation, at least to a slight extent. We, however, consider the measure to be the same so long as we do not perceive any alteration, as I have already remarked.

{Conclusion reached; the difference between ordinary people & philosophers in the matter of judgement.}

22. The consequence of all this is that we are quite unable to obtain a direct knowledge of absolute distances; & we cannot compare them with one another by a common standard. We have to estimate magnitudes by the ideas through which we recognize them; & to take as common standards those measures which ordinary people think suffer no change. But philosophers

should recognize that there is a change; but, since they know of no case in which the equality is destroyed by a perceptible change, they consider that the change is made equally.

{Although, when the ten-foot rod is moved in position, those modes that constitute the relations of the interval are also altered, yet equal intervals are reckoned as same for the reasons stated.}

23. Further, although the distance is really changed when, as in the case of the translation of the ten-foot rod, the position of the points of matter is altered, those real modes which constitute the distance being altered; nevertheless if the change takes place in such a way that the second distance is exactly equal to the first, we shall call it the same, & say that it is altered in no way, so that the equal distances between the same ends will be said to be the same distance & the magnitude will be said to be the same; & this is defined by means of these equal distances, just as also two parallel directions will be also included under the name of the same direction. In what follows we shall say that the distance is not changed, or the direction, unless the magnitude of the distance, or the parallelism, is altered.

{The same observations apply equally to Time; but in it, it is well known, even to ordinary people, that the same temporal interval cannot be translated for the purpose of comparing two intervals; it is because of this that they fall into error with regard to space.}

24. What has been said with regard to the measurement of space, without difficulty can be applied to time; in this also we have no definite & constant measurement. We obtain all that is possible from motion; but we cannot get a motion that is perfectly uniform. We have remarked on many things that belong to this subject, & bear upon the nature & succession of these ideas, in our notes. I will but add here, that, in the measurement of time, not even ordinary people think that the same standard measure of time can be translated from one time to another time. They see that it is another, consider that it is an equal, on account of some assumed uniform motion. Just as with the measurement of time, so in my theory with the measurement of space it is impossible to transfer a fixed length from its place to some other, just as it is impossible to transfer a fixed interval of time, so that it can be used for the purpose of comparing two of them by means of a third. In both cases, a second length, or a second duration is substituted, which is supposed to be equal to the first; that is to say, fresh real positions of the points of the same ten-foot rod which constitute a new distance, such as a new circuit made by the same rod, or a fresh temporal distance between two beginnings & two ends. In my Theory, there is in each case exactly the same analogy between space & time. Ordinary people think that it is only for measurement of space that the standard of measurement is the same; almost all other philosophers except myself hold that it can at least be considered to be the same from the idea that the measure is perfectly solid & continuous, but that in time there is only equality. But I, for my part, only admit in either case the equality, & never the identity."[2890]

Arthur Schopenhauer expressed a "space-time" theory of matter in the early 1800's:

> "§ 4. Whoever has recognised the form of the principle of sufficient reason, which appears in pure time as such, and on which all counting and arithmetical calculation rests, has completely mastered the nature of time. Time is nothing more than that form of the principle of sufficient reason, and has no further significance. Succession is the form of the principle of sufficient reason in time, and succession is the whole nature of time. Further, whoever has recognised the principle of sufficient reason as it appears in the presentation of pure space, has exhausted the whole nature of space, which is absolutely nothing more than that possibility of the reciprocal determination of its parts by each other, which is called position. The detailed treatment of this, and the formulation in abstract conceptions of the results which flow from it, so that they may be more conveniently used, is the subject of the science of geometry. Thus also, whoever has recognised the law of causation, the aspect of the principle of sufficient reason which appears in what fills these forms (space and time) as objects of perception, that is to say matter, has completely mastered the nature of matter as such, for matter is nothing more than causation, as any one will see at once if he reflects. Its true being is its action, nor can we possibly conceive it as having any other meaning. Only as active does it fill space and time; its action upon the immediate object (which is itself matter) determines that perception in which alone it exists. The consequence of the action of any material object upon any other, is known only in so far as the latter acts upon the immediate object in a different way from that in which it acted before; it consists only of this. Cause and effect thus constitute the whole nature of matter; its true being is its action. (A fuller treatment of this will be found in the essay on the Principle of Sufficient Reason, § 21, p. 77.) The nature of all material things is therefore very appropriately called in German *Wirklichkeit*,[1] [*Footnote:* Mira in quibusdam rebus verborum proprietas est, et consuetudo sermonis antiqui quædam efficacissimis notis signat. *Seneca*, epist. 81.] a word which is far more expressive than *Realität*. Again, that which is acted upon is always matter, and thus the whole being and essence of matter consists in the orderly change, which one part of it brings about in another part. The existence of matter is therefore entirely relative, according to a relation which is valid only within its limits, as in the case of time and space.
>
> But time and space, each for itself, can be mentally presented apart from matter, whereas matter cannot be so presented apart from time and space. The form which is inseparable from it presupposes space, and the action in which its very existence consists, always imports some change, in other words a determination in time. But space and time are not only, each for itself, presupposed by matter, but a union of the two constitutes its essence, for this, as we have seen, consists in action, *i. e.*, in causation. All the innumerable conceivable phenomena and conditions of things, might be

coexistent in boundless space, without limiting each other, or might be successive in endless time without interfering with each other: thus a necessary relation of these phenomena to each other, and a law which should regulate them according to such a relation, is by no means needful, would not, indeed, be applicable: it therefore follows that in the case of all co-existence in space and change in time, so long as each of these forms preserves for itself its condition and its course without any connection with the other, there can be no causation, and since causation constitutes the essential nature of matter, there can be no matter. But the law of causation receives its meaning and necessity only from this, that the essence of change does not consist simply in the mere variation of things, but rather in the fact that at the *same part of space* there is now *one thing* and then *another*, and at *one* and the same point of time there is *here* one thing and *there* another: only this reciprocal limitation of space and time by each other gives meaning, and at the same time necessity, to a law, according to which change must take place. What is determined by the law of causality is therefore not merely a succession of things in time, but this succession with reference to a definite space, and not merely existence of things in a particular place, but in this place at a different point of time. Change, *i. e.*, variation which takes place according to the law of causality, implies always a determined part of space and a determined part of time together and in union. Thus causality unites space with time. But we found that the whole essence of matter consisted in action, *i. e.*, in causation, consequently space and time must also be united in matter, that is to say, matter must take to itself at once the distinguishing qualities both of space and time, however much these may be opposed to each other, and must unite in itself what is impossible for each of these independently, that is, the fleeting course of time, with the rigid unchangeable perduration of space: infinite divisibility it receives from both. It is for this reason that we find that co-existence, which could neither be in time alone, for time has no contiguity, nor in space alone, for space has no before, after, or now, is first established through matter. But the co-existence of many things constitutes, in fact, the essence of reality, for through it permanence first becomes possible; for permanence is only knowable in the change of something which is present along with what is permanent, while on the other hand it is only because something permanent is present along with what changes, that the latter gains the special character of change, *i. e.*, the mutation of quality and form in the permanence of substance, that is to say, in matter[1]. [*Footnote:* It is shown in the Appendix that matter and substance are one.] If the world were in space alone, it would be rigid and immovable, without succession, without change, without action; but we know that with action, the idea of matter first appears. Again, if the world were in time alone, all would be fleeting, without persistence, without contiguity, hence without co-existence, and consequently without permanence; so that in this case also there would be no matter. Only through the union of space and time do we reach matter, and matter is the possibility of co-existence, and, through that, of permanence; through permanence again matter is the possibility of the persistence of substance in the change of its states.[2] [*Footnote:* This shows the ground of the Kantian explanation of matter, that it is 'that which is movable in space,' for motion consists simply in the union of space and time.] As matter consists in the union of space and time, it bears throughout the stamp of both. It manifests its origin in space, partly through the form which is inseparable from it, but especially through its persistence (substance), the *a priori* certainty of which is therefore wholly deducible from that of space[3] [*Footnote:* Not, as Kant holds, from the knowledge of time, as will be explained in the Appendix.] (for variation belongs to time alone, but in it alone and for itself nothing is persistent). Matter shows that it springs from time by quality (accidents), without which it never exists, and which is plainly always causality, action upon other matter, and therefore change (a time concept). The law of this action, however, always depends upon space and time together, and only thus obtains meaning. The regulative function of causality is confined entirely to the determination of what must occupy *this time and this space*. The fact that we know *a priori* the unalterable characteristics of matter, depends upon this derivation of its essential nature from the forms of our knowledge of which we are conscious *a priori*. These unalterable characteristics are space-occupation, *i. e.*, impenetrability, *i. e.*, causal action, consequently, extension, infinite divisibility, persistence, *i. e.*, indestructibility, and lastly mobility: weight, on the other hand, notwithstanding its universality, must be attributed to *a posteriori* knowledge, although Kant, in his 'Metaphysical Introduction to Natural Philosophy,' p. 71 (p. 372 of Rosenkranz's edition), treats it as knowable *a priori*.

But as the object in general is only for the subject, as its idea, so every special class of ideas is only for an equally special quality in the subject, which is called a faculty of perception. This subjective correlative of time and space in themselves as empty forms, has been named by Kant pure sensibility; and we may retain this expression, as Kant was the first to treat of the subject, though it is not exact, for sensibility presupposes matter. The subjective correlative of matter or of causation, for these two are the same, is understanding, which is nothing more than this. To know causality is its one function, its only power; and it is a great one, embracing much, of manifold application, yet of unmistakable identity in all its manifestations. Conversely all causation, that is to say, all matter, or the whole of reality, is only for the understanding, through the understanding, and in the understanding. The first, simplest, and ever-present example of understanding is the perception of the actual world. This is throughout knowledge of the cause from the effect, and therefore all perception is intellectual. The understanding could never arrive at this perception, however, if some effect did not become known immediately, and thus serve as a starting-point. But this is the affection of the animal body. So far, then, the animal body is the *immediate object* of the subject; the perception of all other objects becomes possible through it. The changes which every animal body experiences, are immediately known, that is, felt; and as these effects are at once referred to their causes, the perception of the latter as *objects* arises. This relation is no conclusion in abstract conceptions; it does not arise from reflection, nor is it arbitrary, but immediate, necessary, and certain. It is the method of knowing of the pure understanding, without which there could be no perception; there would only remain a dull plant-like consciousness of the changes of the immediate object, which would succeed each other in an utterly unmeaning way, except in so far as they might have a meaning for the will either as pain or pleasure. But as with the rising of the sun the visible world appears, so at one stroke, the understanding, by means of its one simple function, changes the dull, meaningless sensation into perception. What the eye, the ear, or the hand feels, is not perception; it is merely its data. By the understanding passing from the effect to the cause, the world first appears as perception extended in space, varying in respect of form, persistent through all time in respect of matter; for the understanding unites space and time in the idea of matter, that is, causal action. As the world as idea exists only through the understanding, so also it exists only for the understanding. In the first chapter of my essay on ‘Light and Colour,’ I have already explained how the understanding constructs perceptions out of the data supplied by the senses; how by comparison of the impressions which the various senses receive from the object, a child arrives at perceptions; how this alone affords the solution of so many phenomena of the senses; the single vision of two eyes, the double vision in the case of a squint, or when we try to look at once at objects which lie at unequal distances behind each other; and all illusion which is produced by a sudden alteration in the organs of sense. But I have treated this important subject much more fully and thoroughly in the second edition of the essay on ‘The Principle of Sufficient Reason,’ § 21. All that is said there would find its proper place here, and would therefore have to be said again; but as I have almost as much disinclination to quote myself as to quote others, and as I am unable to explain the subject better than it is explained there, I refer the reader to it, instead of quoting it, and take for granted that it is known.

The process by which children, and persons born blind who have been operated upon, learn to see, the single vision of the double sensation of two eyes, the double vision and double touch which occur when the organs of sense have been displaced from their usual position, the upright appearance of objects while the picture on the retina is upside down, the attributing of colour to the outward objects, whereas it is merely an inner function, a division through polarisation, of the activity of the eye, and lastly the stereoscope,—all these are sure and incontrovertible evidence that perception is not merely of the senses, but intellectual— that is, *pure knowledge through the understanding of the cause from the effect*, and that, consequently, it presupposes the law of causality, in a knowledge of which all perception—that is to say all experience, by virtue of its primary and only possibility, depends. The contrary doctrine that the law of causality results from experience, which was the scepticism of Hume, is first refuted by this. For the independence of the knowledge of causality of all experience,—that is, its *a priori* character—can only be deduced from the dependence of all experience upon it; and this deduction can only be accomplished by proving, in the manner here indicated, and explained in the passages referred to above, that the knowledge of causality is included in perception in general, to which all experience belongs, and therefore in respect of experience is completely *a priori*, does not presuppose it, but is presupposed by it as a condition. This, however, cannot be deduced in the manner attempted by Kant, which I have criticised in the essay on 'The Principle of Sufficient Reason,' § 23."[2891]

Ernst Mach wrote:

"Obviously it does not matter whether we think of the earth as turning round on its axis, or at rest while the celestial bodies revolve round it. Geometrically these are exactly the same case of a relative rotation of the earth and of the celestial bodies with respect to one another. Only, the first representation is astronomically more convenient and simpler.

But if we think of the earth at rest and the other celestial bodies revolving round it, there is no flattening of the earth, no Foucault's experiment, and so on—at least according to our usual conception of the law of inertia. Now, one can solve the difficulty in two ways: Either all motion is absolute, or our law of inertia is wrongly expressed. Neumann preferred the first supposition, I, the second. The law of inertia must be so conceived that exactly the same thing results from the second supposition as from the first. By this it will be evident that, in its expression, regard must be paid to the masses of the universe.

In ordinary terrestrial cases, it will answer our purposes quite well to reckon the direction and velocity with respect to the top of a tower or a corner of a room; in ordinary astronomical cases, one or other of the stars will suffice. But because we can also choose other corners of rooms, another pinnacle, or other stars, the view may easily arise that we do not need such a point at all from which to reckon. But this is a mistake; such a system of co-ordinates has a value only if it can be determined by means of bodies. We here fall into the same error as we did with the representation of time. Because a piece of paper money need not necessarily be funded by a definite piece of money, we must not think that it need not be funded at all.

In fact, any one of the above points of origin of co-ordinates answers our purposes as long as a sufficient number of bodies keep fixed positions with respect to one another. But if we wish to apply the law of inertia in an earthquake, the terrestrial points of reference would leave us in the lurch, and, convinced of their uselessness, we would grope after celestial ones. But, with these better ones, the same thing would happen as soon as the stars showed movements which were very noticeable. When the variations of the positions of the fixed stars with respect to one another cannot be disregarded, the laying down of a system of co-ordinates has reached an end. It ceases to be immaterial whether we take this or that star as point of reference; and we can no longer reduce these systems to one another. We ask for the first time which star we are to choose, and in this case easily see that the stars cannot be treated indifferently, but that because we can give preference to none, the influence of all must be taken into consideration.

We can, in the application of the law of inertia, disregard any particular body, provided that we have enough other bodies which are fixed with respect to one another. If a tower falls, this does not matter to us; we have others. If Sirius alone, like a shooting-star, shot through the heavens, it would not disturb us very much; other stars would be there. But what would become of the law of inertia if the whole of the heavens began to move and the stars swarmed in confusion? How would we apply it then? How would it have to be expressed then? We do not inquire after one body as long as we have others enough; nor after one piece of money as long as we have others enough. Only in the case of a shattering of the universe, or a bankruptcy, as the case may be, we learn that *all* bodies, each with its share, are of importance in the law of inertia, and all money, when paper money is funded, is of importance, each piece having its share.

Yet another example: A free body, when acted upon by an instantaneous couple, moves so that its central ellipsoid with fixed centre rolls without slipping on a tangent-plane parallel to the plane of the couple. This is a motion in consequence of inertia. Here the body makes very strange motions with respect to the celestial bodies. Now, do we think that these bodies, without which one cannot describe the motion imagined, are without influence on this motion? Does not that to which one must appeal explicitly or implicitly when one wishes to describe a phenomenon belong to the most essential conditions, to the causal nexus of the phenomenon? The distant heavenly bodies have, in our example, no influence on the acceleration, but they have on the velocity.

Now, what share has every mass in the determination of direction and velocity in the law of inertia? No definite answer can be given to this by our experiences. We only know that the share of the nearest masses vanishes in comparison with that of the farthest. We would, then, be able completely to make out the facts known to us if, for example, we were to make the simple supposition that all bodies act in the way of determination proportionately to their masses and independently of the distance, or proportionately to the distance, and so on. Another expression would be: In so far as bodies are so distant from one another that they contribute no noticeable acceleration to one another, all distances vary proportionately to one another.

[***]

ON THE DEFINITION OF MASS

The circumstance that the fundamental propositions of mechanics are neither wholly *a priori* nor can wholly be discovered by means of experience—for sufficiently numerous and accurate experiments cannot be made—results in a peculiarly inaccurate and unscientific treatment of these fundamental propositions and conceptions. Rarely is distinguished and stated clearly enough what is *a priori*, what empirical, and what is hypothesis.

Now, I can only imagine a scientific exposition of the fundamental propositions of mechanics to be such that one regards these theorems as hypotheses to which experience forces us, and that one afterwards shows how the denial of these hypotheses would lead to contradictions with the best-established facts.

As evident *a priori* we can only, in scientific investigations, consider the law of causality or the law of sufficient reason, which is only another form of the law of causality. No investigator of nature doubts that under the same circumstances the same always results, or that the effect is completely determined by the cause. It may remain undecided whether the law of causality rests on a powerful induction or has its foundation in the psychical organization (because in the psychic life, too, equal circumstances have equal consequences).

The importance of the law of sufficient reason in the hands of an investigator was proved by Clausius's works on thermodynamics and Kirchhoff's researches on the connexion of absorption and emission. The well-trained investigator accustoms himself in his thought, by the aid of this theorem, to the same definiteness as nature has in its actions, and then experiences which are not in themselves very apparent suffice, by exclusion of all that is contradictory, to discover very important laws connected with the said experiences.

Usually, now, people are not very chary of asserting that a proposition is immediately evident. For example, the law of inertia is often stated to be such a proposition, as if it did not need the proof of experience. The fact is that it can only have grown out of experience. If masses imparted to one another, not acceleration, but, say, velocities which depended on the distance, there would be no law of inertia; but whether we have the one state of things or the other, only experience teaches. If we had merely sensations of heat, there would be merely equalizing velocities (*Ausgleichungsgeschwindigkeiten*), which vanish with the differences of temperature.

One can say of the motion of masses: 'The effect of every cause persists,' just as correctly as the opposite: 'Cessante causa cessat effectus'; it is merely a matter of words. If we call the resulting velocity the 'effect,' the first proposition is true, if we call the acceleration the 'effect,' the second is true.

Also people try to deduce *a priori* the theorem of the parallelogram of forces; but they must always bring in tacitly the supposition that the forces are independent of one another. But by this the whole derivation becomes superfluous.

I will now illustrate what I have said by *one* example, and show how I think the conception of mass can be quite scientifically developed. The difficulty of this conception, which is pretty generally felt, lies, it seems to me, in two circumstances: (1) in the unsuitable arrangement of the first conceptions and theorems of mechanics; (2) in the silent passing over important presuppositions lying at the basis of the deduction.

Usually people define $m = \frac{p}{g}$ and again $p = mg$. This is either a very repugnant circle, or it is necessary for one to conceive force as ‘pressure.’ The latter cannot be avoided if, as is customary, statics precedes dynamics. The difficulty, in this case, of defining magnitude and direction of a force is well-known.

In that principle of Newton, which is usually placed at the head of mechanics, and which runs: ‘Actioni contrariam semper et aequalem esse reactionem: sive corporum duorum actiones in se mutuo semper esse aequales et in partes contrarias dirigi,’ the actio is again a pressure, or the principle is quite unintelligible unless we possess already the conception of force and mass. But pressure looks very strange at the head of the quite phoronomical mechanics of today. However, this can be avoided.

If there were only one kind of matter, the law of sufficient reason would be sufficient to enable us to perceive that two completely similar bodies can impart to each other only *equal* and *opposite* accelerations. This is the one and only effect which is completely determined by the cause.

Now, if we suppose the mutual independence of forces, the following easily results. A body A, consisting of m bodies a, is the presence of another body B, consisting of m' bodies a. Let the acceleration of A be φ and that of B be φ'. Then we have $\varphi : \varphi' = m' : m$.

If we say that a body A has the mass m if it contains the body a m times, this means that the accelerations vary as the masses.

To find by experiment the mass-ratio of two bodies, let us allow them to act on one another, and we get, when we pay attention to the sign of the acceleration, $\frac{m}{m'} = -\left(\frac{\varphi'}{\varphi}\right)$.

If the one body is taken as a unit of mass, the calculation gives the mass of the other body. Now, nothing prevents us from applying this definition in cases in which two bodies of different matter act on one another. Only, we cannot know *a priori* whether we do not obtain other values for a mass when we consult other bodies used for purposes of comparison and other forces. When it was found that A and B combine chemically in the ratio $a : b$ of their weights and that A and C do so in the ratio $a : c$ of their weights, it could not be known beforehand that B and C combine in the ratio $b : c$. Only experience can teach us that two bodies which behave to a third as equal masses will also behave to one another as equal masses.

If a piece of gold is opposed to a piece of lead, the law of sufficient reason leaves us completely. We are not even justified in expecting contrary motions: both bodies might accelerate in the same direction. The calculation would then lead to negative masses.

But that two bodies which behave as equal masses to a third behave as such to one another, with respect to any forces, is very likely, because the contrary would not be reconcilable with the law of the conservation of work (*Kraft*), which has hitherto been found to be valid.

Imagine three bodies A, B, and C movable on an absolutely smooth and absolutely fixed ring. The bodies are to act on one another with any forces. Further, both A and B, on the one hand, and A and C, on the other, are to behave to one another as equal masses. Then the same must hold between B and C.

If, for example, C behaved to B as a greater mass to a lesser one, and we gave B a velocity in the direction of the arrow, it would give this velocity wholly to A by impact, and A would give it wholly to C. Then C would communicate to B a greater velocity and yet keep some itself. With every revolution in the direction of the arrow, then, the *vis viva* in the ring would increase; and the contrary would take place if the original motion were in a direction opposite to that of the arrow. But this would be in glaring contradiction with the facts hitherto known.

If we have thus defined mass, nothing prevents us from keeping the old definition of force as product of mass and acceleration. The law of Newton mentioned above then becomes a mere identity.

Since all bodies receive from the earth an equal acceleration, we have in this force (their weight) a convenient measure of their masses; again, however, only under the two suppositions that bodies which behave as equal masses to the earth do so to one another, and with respect to every force. Consequently, the following arrangement of the theorems of mechanics would appear to me to be the most scientific.

Theorem of experience.—Bodies placed opposite to one another communicate to each other accelerations in opposite senses in the direction of their line of junction. The law of inertia is included in this.

Definition.—Bodies which communicate to each other equal and opposite accelerations are said to be of equal mass. We get the mass-value of a body by dividing the acceleration which it gives the body with which we compare others, and choose as the unit, by the acceleration which it gets itself.

Theorem of experience.—The mass-values remain unaltered when they are determined with reference to other forces and to another body of comparison which behaves to the first one as an equal mass.

Theorem of experience.—The accelerations which many masses communicate to one another are mutually independent. The theorem of the parallelogram of forces is included in this.

Definition.—Force is the product of the mass-value of a body into the acceleration communicated to that body."[2892]

Fechner stated,

"All that is given is what can be seen and felt, movement and the laws of movement. How then can we speak of force here? For physics, force is nothing but an auxiliary expression for presenting the laws of equilibrium and of motion; and every clear interpretation of physical force brings us back to this. We speak of laws of force; but when we look at the matter more closely, we find that they are merely laws of equilibrium and movement which hold for matter in the presence of matter. To say that the sun and the earth exercise an attraction upon one another, simply means that the sun and earth behave in relation to one another in accordance with definite laws. To the physicist, force is but a law, and in no other way does he know how to describe it. . . All that the physicist deduces from his forces is merely an inference from laws, through the instrumentality of the auxiliary word 'force'."[2893]

In his professorial address, Hendrik Antoon Lorentz avowed,

"The word 'forces' is but a name for certain entities present in our formulae[.]"[2894]

In 1877, Frederick William Frankland stated,

"[T] he conception of space is a particular variety of a wider and more general conception. This wider conception, of which time and space are particular varieties, it has been proposed to denote by the term manifoldness."[2895]

In an argument dating as far back as 1870, the journal *Mind* published an article by Frankland in 1881, which set forth a version of "Mach's principle":

"Our first step will show us how thoroughly interdependent all these conceptions are. *Matter* can only be defined as that which possesses *inertia*—as that which requires a *force* proportional to its amount (designated its *mass*) to effect a given change in its *motion* (either a change in velocity, or a change in direction, or both) in a given *time*. *Force*, again, can only be defined as that which causes a change in the velocity or direction of the *motion* of *matter*. It is tacitly assumed, though not often expressed, that the only thing which can cause such a change in velocity or direction is the co-existence of other matter. This amounts to saying that force is a relation of co-existence between different portions of matter. But every relation of co-existence in the material or phenomenal world is a relation of mutual positions in space. Hence force is a relation of mutual position between different portions of matter. *Motion*, in the kinetic, or dynamical, as opposed to the merely kinematical sense, is a change in the position of *matter*, and is completely determined when the mass of the moving body and the kinematical conditions of the case are given. The notion of *energy* does not require the introduction of any fundamentally new conception. Hence the phenomenal world is accurately described if we speak of it as a complex of motions, varying in infinite ways as regards mass on the one hand, and velocity and the other kinematical aspects on the other, tending severally to constancy in all these respects, but having a mutual action on one another, determined by their relations of co-existence, and, therefore, undergoing perpetual transformation. Now mark the parallelism. The noumenal world, we have seen, may be described as a complex of feeling elements, or Mind-Stuff units, having, just as motion has, extension in Time, varying in infinite ways as regards volume, intensity, and quality or timbre, having a mutual action on one another, determined by their mutual relations of co-existence, and undergoing perpetual transformations."[2896]

W. K. Clifford published an influential article in 1878, "On the Nature of Things-inThemselves",

"Mind-stuff is the reality which we perceive as Matter. [***] Matter is a mental picture in which mind-stuff is the thing represented."[2897]

It is interesting to note that Cunningham, in 1914, uses Clifford's term "mind-stuff" (which perhaps derives from Riemann) in the context of Minkowski's "imaginary space of four dimensions".[2898] Eddington (appropriately enough also, like Frankland, in the journal *Mind*) later in 1920 relegated many aspects of Physics to solipsism, as if this were a novel approach by Einstein, when it clearly was not,

"THE theory of relativity has introduced into physics new conceptions of time and space, which have aroused widespread interest. Less attention has been paid to the position of matter in the new theory; but a natural interpretation suggests a view of the nature of matter, which is in some respects novel and is more precise than the theories hitherto current. It is perhaps a commonplace that, whatever may be the true nature of matter, it is the *mind* which from the crude substratum constructs the familiar picture of a substantial world around us. On the present theory we seem able to discern something of the motives of the mind in selecting and endowing with substantiality one particular quality of the external world, and to see that practically no other choice was possible for the rational mind. It will appear in the discussion that many of the best-known laws of physics are not inherent in the external world, but were automatically imposed by mind when it made the selection."[2899]

R. B. Braithwaite stated in 1929,

"Mr. Eddington's metaphysic is, it is true, what W. K. Clifford's would have been had he been a member of the Society of Friends instead of a militant atheist[.]"[2900]

And, indeed, Eddington had quoted Clifford in a long section of his Gifford lectures of 1927dedicated to the definition of "*Mind-Stuff"*,

"The mind-stuff is the aggregation of relations and relata which form the building material for the physical world. Our account of the building process shows, however, that much that is implied in the relations is dropped as unserviceable for the required building. Our view is practically that urged in 1875 by W. K. Clifford—

'The succession of feelings which constitutes a man's consciousness is the reality which produces in our minds the perception of the motions of his brain.'

That is to say, that which the man himself knows as a succession of feelings is the reality which when probed by the appliances of an outside investigator affects their readings in such a way that it is identified as a configuration of brain-matter."[2901]

David Hilbert declared in the concluding paragraph of his 1915 lecture "The Foundations of Physics" that "the possibility draws near that in principle from Physics a science evolves which is a type of geometry". In the 1800's, the anti-Kantian Bolliger sought to attribute gravity to geometry, as did W. W. R. Ball.[2902]

In 1881, Johann Bernhard Stallo summarized the movement to abolish the term "force" from Physics, a movement often wrongfully attributed to Einstein,[2903] as if originator,

"The prevailing errors respecting the inertia of matter have naturally led to corresponding delusions as to the nature of force. Here we are met, *in limine*, by an ambiguity in the meaning of the term force in physics and mechanics. When we speak of a 'force of nature,' we use the word force in a sense very different from that which it bears in mechanics. A 'force of nature,' is a survival of ontological speculation; in common phraseology the term stands for a distinct and real entity. But, as a determinate mechanical function, force is simply the rate of change of momentum—mathematically expressed, the differential of momentum at a given instant of time. 'Momentum,' says Mr. Tait, [*Footnote:* On Some Recent Advances in Physical Science, second ed., p. 347.] 'is the time-integral of force, because force is the rate of change of momentum.' In the canonical text-books on physics, force is defined as the cause of motion. 'Any cause,' says Whewell, [*Footnote:* Mechanics, p. 1.] 'which moves or tends to move a body, or which changes or tends to change its motion, is called force.' So Clerk Maxwell: [*Footnote:* Theory of Heat, p. 83.] 'Force is whatever changes or tends to change the motion of a body by altering either its direction or its magnitude.' Far greater insight into the nature of force is exhibited in the definition of Somoff, though the word 'cause' is retained: 'A material point is moved by the presence of matter without it. This action of extraneous matter is attributed to a cause which is named force.' [*Footnote:* Somoff, Theoretische Mechanik (trans. by Ziwet), vol. ii, p. 155.] Taking these definitions as correctly representing the received theories of physical science, it is manifest, irrespective of the considerations I have presented in this and the preceding chapters, that force is not an individual thing or entity that presents itself directly to observation or to thought, but that, so far as it is treated as a definite and unital term in the operations of thought, it is purely an incident to the conception of the interdependence of moving masses. The cause of motion, or of the change of motion, in a body is the condition or group of conditions upon which the motion depends; and this condition or group of conditions is always a corresponding motion, or change of motion, of the bodies outside of the body in question which are its dynamical correlates. [*Footnote:* 'Der gegenwaertig klar entwickelte mechanische Begriff der Kraft,' says Zoellner (Natur der Kometen, p. 328), 'enthaelt nichts Anders als den Ausdruck einer raeumlichen und zeitlichen Beziehung zweier Koerper.'] Otherwise expressed, force is a mere inference from the motion itself under the universal conditions of reality, and its measure and determination lie solely in the effect for which it is postulated as a cause; it has no other existence. The only reality of force and its action is the correspondence between physical phenomena in conformity with the principle of the essential relativity of all forms of physical existence.

That force has no independent reality is so plain and obvious that it has been proposed by some thinkers to abolish the term *force*, like the term *cause*, altogether. However desirable a sparing use of such terms may be (as is illustrated in the clearness of some modern mechanical treatises [*Footnote:* Cf. e. g. Kirchhoff, Vorlesgungen ueber mathematische Physik. Heidelberg, 1876.]), it is impracticable wholly to dispense with it, for the reason that the conceptual element force, when properly interpreted in terms of experience, is a legitimate incident to the conception of physical action, and, if its name were disused, it would instantly reappear under another name. There are few concepts which have not, in science as well as in metaphysics, given rise to the same confusion that prevails in regard to 'force' and 'cause;' and the blow leveled at these would demolish all concepts whatever. Nevertheless, it is of the greatest moment, in all speculations concerning the interdependence of physical phenomena, never to lose sight of the fact that force is a purely conceptual term, and that it is not a distinct tangible or intangible thing."[2904]

In the Nineteenth Century, Robert Mayer, and many others argued for the "correlation and conservation of force."[2905] Also in the Nineteenth Century, among the Anti-Kantians, Monists, mathematicians, Positivists, æther theorists and field theorists, there were primarily two schools of thought *pushing* for the abandonment of the term "force" as a mystical Newtonian concept. One school opposed the Newtonian mythology of "action at a distance" and sought the unification of all "forces" long before Einstein pursued Hilbert's goal of a unified field theory. Hilbert wrote in 1915,

> "Wie man sieht, genügen bei sinngemäßer Deutung die wenigen einfachen in den Axiomen I und II ausgesprochenen Annahmen zum Aufbau der Theorie: durch dieselbe werden nicht nur unsere Vorstellungen über Raum, Zeit und Bewegung von Grund aus in dem von E i n s t e i n dargelegten Sinne umgestaltet, sondern ich bin auch der Überzeugung, daß durch die hier aufgestellten Grundgleichungen die intimsten bisher verborgenen Vorgänge innerhalb des Atoms Aufklärung erhalten werden und insbesondere allgemein eine Zurückführung aller physikalischen Konstanten auf mathematische Konstanten möglich sein muß — wie denn überhaupt damit die Möglichkeit naherückt, daß aus der Physik im Prinzip eine Wissenschaft von der Art der Geometrie werde: gewiß der herrlichste Ruhm der axiomatischen Methode, die hier wie wir sehen die mächtigen Instrumente der Analysis, nämlich Variationsrechnung und Invariantentheorie, in ihre Dienste nimmt."[2906]

This school included Pasley,[2907] Faraday,[2908] Secchi,[2909] Anderssohn,[2910] Spiller,[2911] Vogt,[2912] Haeckel,[2913] Jahr,[2914] Sutherland,[2915] See,[2916] Wiechert,[2917] etc. and most of them sought a universal æther as a cause of the motions hitherto attributed to mystical nondescript "force". The other school included Herbart,[2918] Mossotti,[2919] Poe,[2920] Dühring,[2921] Mach,[2922] Bolliger,[2923] Stallo,[2924] Geissler,[2925] Noble,[2926] Hilbert,[2927] etc. and they believed in relativity, geometry and multiplicity as the apparent "cause" of the seeming "effects" attributed to mysterious Newtonian "forces". This all happened long before Lorentz,[2928] Ishiwara,[2929] de Donder,[2930] Nordström,[2931] Einstein, Weyl,[2932] Thirring,[2933] Kaluza[2934] and Klein, etc. took up the research program of the unification of forces and fields in the theory of relativity, which followed directly from Faraday's experimental work.[2935]

Schopenhauer stated in 1819 in his book *The World as Will and Representation*,

> "Force and substance are inseparable, because at bottom they are one; for, as Kant has shown, matter itself is given to us only as the union of forces, that

of expansion and that of attraction. Therefore there exists no opposition between force and substance; on the contrary, they are precisely one."[2936]

Michael Faraday, like many others, pursued Boscovich's atomic theory of atoms as point centers of force and expressed Dynamism as a field theory without an æther. Faraday was inspired by Peter Mark Roget, famous for the theory of persistent vision and for his thesaurus. The editors of the English translation of Mossotti's influential article "On the Forces which regulate the Internal Constitution of Bodies", *Scientific Memoirs*, Volume 1, Richard Taylor, London, (1837), pp. 448-469; included the following endnote:

"[The readers of this Memoir will doubtless be interested in referring to Dr. Roget's "Treatise on Electricity" in the Library of Useful Knowledge, published March 15th, 1828; the following passage from which was noticed with reference to M. Mossotti's views, by Prof. Faraday in his lecture at the Royal Institution, Jan. 20th of the present year.— EDIT.]

'(239.) It is a great though a common error to imagine, that the condition assumed by Æpinus, namely that the particles of matter when devoid of electricity repel one another, is in opposition to the law of universal gravitation established by the researches of Newton; for this law applies, in every instance to which inquiry has extended, to matter in its ordinary state; that is, combined with a certain proportion of electric fluid. By supposing, indeed, that the mutual repulsive action between the particles of matter is, by a very small quantity, less than that between the particles of the electric fluid, a small balance would be left in favour of the attraction of neutral bodies for one another, which might constitute the very force which operates under the name of gravitation; and thus both classes of phænomena may be included in the same law.'"

Edgar Allen Poe wrote in his Monistic and Dynamystic *Eureka: A Prose Poem* of 1848, which contains many of the elements of modern relativity theory,

"Discarding now the two equivocal terms, 'gravitation' and 'electricity,' let us adopt the more definite expressions, '*Attraction*' and '*Repulsion*.' The former is the body, the latter the soul; the one is the material, the other the spiritual, principle of the Universe. *No other principles exist. All* phenomena are referable to one, or to the other, or to both combined. So rigorously is this the case, so thoroughly demonstrable is it that Attraction and Repulsion are the *sole* properties through which we perceive the Universe—in other words, by which Matter is manifested to Mind — that, for all merely argumentative purposes, we are fully justified in assuming that Matter *exists* only as Attraction and Repulsion—that Attraction and Repulsion *are* matter; there being no conceivable case in which we may not employ the term 'Matter' and the terms 'Attraction' and 'Repulsion,' taken together, as equivalent, and therefore convertible, expressions in Logic."[2937]

Faraday wrote in 1845,

> "2146. I HAVE long held an opinion, almost amounting to conviction, in common I believe with many other lovers of natural knowledge, that the various forms under which the forces of matter are made manifest have one common origin; or, in other words, are so directly related and mutually dependent, that they are convertible, as it were, one into another, and possess equivalents of power in their action. [*Footnote: Experimental Researches*, 57, 366, 376, 877, 961, 2071.] In modern times the proofs of their convertibility have been accumulated to a very considerable extent, and a commencement made of the determination of their equivalent forces."[2938]

Faraday's statement caught the attention of Sir Edward Bulwer-Lytton, who referred to it soon after in Chapter 7 of his novel *The Coming Race*,

> "'What is vril?' I asked.
>
> Therewith Zee began to enter into an explanation of which I understood very little, for there is no word in any language I know which is an exact synonym for vril. I should call it electricity, except that it comprehends in its manifold branches other forces of nature, to which, in our scientific nomenclature, differing names are assigned, such as magnetism, galvanism, etc. These people consider that in vril they have arrived at the unity in natural energetic agencies, which has been conjectured by many philosophers above ground, and which Faraday thus intimates under the more cautious term of 'correlation':—
>
> 'I have long held an opinion,' says that illustrious experimentalist, 'almost amounting to a conviction, in common, I believe, with many other lovers of natural knowledge, that the various forms under which the forces of matter are made manifest have one common origin; or, in other words, are so directly related and mutually dependent, that they are convertible, as it were, into one another, and possess equivalents of power in their action.'
>
> These subterranean philosophers assert that, by one operation of vril, which Faraday would perhaps call 'atmospheric magnetism,' they can influence the variations of temperature—in plain words, the weather; that by other operations, akin to those ascribed to mesmerism, electro-biology, odic force, etc., but applied scientifically through vril conductors, they can exercise influence over minds, and bodies animal and vegetable, to an extent not surpassed in the romances of our mystics. To all such agencies they give the common name of 'vril.'"[2939]

Helene Petrovna Blavatsky in turn referred to both Faraday's statement and Bulwer-Lytton's "vril" in her *Isis Unveiled: A Master-key to the Mysteries of Ancient and Modern Science and Theology*, Volume 1, Chapter 5, J.W. Bouton, New York, (1877), pp. 125-126,

> "Sir E. Bulwer-Lytton, in his *Coming Race*, describes it as the VRIL,[*Footnote:* We apprehend that the noble author coined his curious names by contracting words in classical languages. Gy would come from gune; vril from virile.] used by the subterranean populations, and allowed his readers to take it for a fiction. 'These people,' he says, 'consider that in the vril they had arrived at the unity in natural energic agencies'; and proceeds to show that Faraday intimated them 'under the more cautious term of correlation,' thus:
>
> 'I have long held an opinion, almost amounting to a conviction, in common, I believe, with many other lovers of natural knowledge, that the various forms under which the forces of matter are made manifest, HAVE ONE COMMON ORIGIN; or, in other words, are so directly related and naturally dependent, that they are convertible, as it were, into one another, and possess equivalents of power in their action.'
>
> Absurd and unscientific as may appear our comparison of a fictitious vril invented by the great novelist, and the primal force of the equally great experimentalist, with the kabalistic astral light, it is nevertheless the true definition of this force."

Faraday stated in 1850,

> "2702. THE long and constant persuasion that all the forces of nature are mutually dependent, having one common origin, or rather being different manifestations of one fundamental power (2146), has made me often think upon the possibility of establishing by experiment, a connexion between gravity and electricity, and so introducing the former into the group, the chain of which, including also magnetism, chemical force and heat, binds so many and such varied exhibitions of force together by common relations. Though the researches I have made with this object in view have produced only negative results, yet I think a short statement of the matter, as it has presented itself to my mind, and of the result of the experiments, which offering at first much to encourage, were only reduced to their true value by most careful searchings after sources of error, may be useful, both as a general statement of the problem, and as awakening the minds of others to its consideration."[2940]

Faraday argued, on 15 April 1846,

> "AT your request I will endeavour to convey to you a notion of that which I ventured to say at the close of the last Friday-evening Meeting, incidental to the account I gave of Wheatstone's electro-magnetic chronoscope; but from first to last understand that I merely threw out as matter for speculation, the vague impressions of my mind, for I gave nothing as the result of

sufficient consideration, or as the settled conviction, or even probable conclusion at which I had arrived.

The point intended to be set forth for consideration of the hearers was, whether it was not possible that the vibrations which in a certain theory are assumed to account for radiation and radiant phænomena may not occur in the lines of force which connect particles, and consequently masses of matter together; a notion which as far as it is admitted, will dispense with the æther, which, in another view, is supposed to be the medium in which these vibrations take place.

You are aware of the speculation [*Footnote:* Philosophical Magazine, 1844, vol xxiv, p136; or Exp. Res. ii.284.] which I some time since uttered respecting that view of the nature of matter which considers its ultimate atoms as centres of force, and not as so many little bodies surrounded by forces, the bodies being considered in the abstract as independent of the forces and capable of existing without them. In the latter view, these little particles have a definite form and a certain limited size; in the former view such is not the case, for that which represents size may be considered as extending to any distance to which the lines of force of the particle extend: the particle indeed is supposed to exist only by these forces, and where they are it is. The consideration of matter under this view gradually led me to look at the lines of force as being perhaps the seat of the vibrations of radiant phænomena.

Another consideration bearing conjointly on the hypothetical view both of matter and radiation, arises from the comparison of the velocities with which the radiant action and certain powers of matter are transmitted. The velocity of light through space is about 190,000 miles in a second; the velocity of electricity is, by the experiments of Wheatstone, shown to be as great as this, if not greater: the light is supposed to be transmitted by vibrations through an aether which is, so to speak, destitute of gravitation, but infinite in elasticity; the electricity is transmitted through a small metallic wire, and is often viewed as transmitted by vibrations also. That the electric transference depends on the forces or powers of the matter of the wire can hardly be doubted, when we consider the different conductibility of the various metallic and other bodies; the means of affecting it by heat or cold; the way in which conducting bodies by combination enter into the constitution of non-conducting substances, and the contrary; and the actual existence of one elementary body, carbon, both in the conducting and non-conducting state. The power of electric conduction (being a transmission of force equal in velocity to that of light) appears to be tied up in and dependent upon the properties of the matter, and is, as it were, existent in them.

I suppose we may compare together the matter of the æther and ordinary matter (as, for instance, the copper of the wire through which the electricity is conducted), and consider them as alike in their essential constitution; *i. e.* either as both composed of little nuclei, considered in the abstract as matter, and of force or power associated with these nuclei, or else both consisting of mere centres of force, according to Boscovich's theory and the view put forth in my speculation; for there is no reason to assume that the nuclei are more requisite in the one case than in the other. It is true that the copper gravitates and the æther does not, and that therefore the copper is ponderable and the æther is not; but that cannot indicate the presence of nuclei in the copper more than in the æther, for of all the powers of matter gravitation is the one in which the force extends to the greatest possible distance from the supposed nucleus, being infinite in relation to the size of the latter, and reducing that nucleus to a mere centre of force. The smallest atom of matter on the earth acts directly on the smallest atom of matter in the sun, though they are 95,000,000 miles apart; further, atoms which, to our knowledge, are at least nineteen times that distance, and indeed in cometary masses, far more, are in a similar way tied together by the lines of force extending from and belonging to each. What is there in the condition of the particles of the supposed æther, if there be even only *one* such particle between us and the sun, that can in subtility and extent compare to this?

Let us not be confused by the *ponderability* and *gravitation* of heavy matter, as if they proved the presence of the abstract nuclei; these are due not to the nuclei, but to the force super-added to them, if the nuclei exist at all; and, if the *æther* particles be without this force, which according to the assumption is the case, then they are more material, in the abstract sense, than the matter of this our globe; for matter, according to the assumption, being made up of nuclei and force, the æther particles have in this respect proportionately more of the nucleus and less of the force.

On the other hand, the infinite elasticity assumed as belonging to the particles of the æther, is as striking and positive a force of it as gravity is of ponderable particles, and produces in its way effects as great; in witness whereof we have all the varieties of radiant agency as exhibited in luminous, calorific, and actinic phænomena.

Perhaps I am in error in thinking the idea generally formed of the æther is that its nuclei are almost infinitely small, and that such force as it has, namely its elasticity, is almost infinitely intense. But if such be the received notion, what then is left in the æther but force or centres of force? As gravitation and solidity do not belong to it, perhaps many may admit this conclusion; but what are gravitation and solidity? certainly not the weight and contact of the abstract nuclei. The one is the consequence of an *attractive* force, which can act at distances as great as the mind of man can estimate or conceive; and the other is the consequence of a *repulsive* force, which forbids for ever the contact or touch of any two nuclei; so that these powers or properties should not in any degree lead those persons who conceive of the æther as a thing consisting of force only, to think any otherwise of ponderable matter, except that it has more and other *forces* associated with it than the æther has.

In experimental philosophy we can, by the phænomena presented, recognize various kinds of lines of force; thus there are the lines of gravitating force, those of electro-static induction, those of magnetic action, and others partaking of a dynamic character might be perhaps included. The lines of electric and magnetic action are by many considered as exerted through space like the lines of gravitating force. For my own part, I incline to believe that when there are intervening particles of matter (being themselves only centres of force), they take part in carrying on the force through the line, but that when there are none, the line proceeds through space. [*Footnote:* Experimental Researches in Electricity, pars. 1161, 1613, 1663, 1770, 1729, 1735, 2443.] Whatever the view adopted respecting them may be, we can, at all events, affect these lines of force in a manner which may be conceived as partaking of the nature of a shake or lateral vibration. For suppose two bodies, A B, distant from each other and under mutual action, and therefore connected by lines of force, and let us fix our attention upon one resultant of force, having an invariable direction as regards space; if one of the bodies move in the least degree right or left, or if its power be shifted for a moment within the mass (neither of these cases being difficult to realise if A and B be either electric or magnetic bodies), then an effect equivalent to a lateral disturbance will take place in the resultant upon which we are fixing our attention; for, either it will increase in force whilst the neighboring results are diminishing, or it will fall in force as they are increasing.

It may be asked, what lines of force are there in nature which are fitted to convey such an action and supply for the vibrating theory the place of the æther? I do not pretend to answer this question with any confidence; all I can say is, that I do not perceive in any part of space, whether (to use the common phrase) vacant or filled with matter, anything but forces and the lines in which they are exerted. The lines of weight or gravitating force are, certainly, extensive enough to answer in this respect any demand made upon them by radiant phænomena; and so, probably, are the lines of magnetic force: and then who can forget that Mossotti has shown that gravitation, aggregation, electric force, and electro-chemical action may all have one common connection or origin; and so, in their actions at a distance, may have in common that infinite scope which some of these actions are known to possess?

The view which I am so bold as to put forth considers, therefore, radiation as a high species of vibration in the lines of force which are known to connect particles and also masses of matter together. It endeavours to dismiss the æther, but not the vibration. The kind of vibration which, I believe, can alone account for the wonderful, varied, and beautiful phænomena of polarization, is not the same as that which occurs on the surface of disturbed water, or the waves of sound in gases or liquids, for the vibrations in these cases are direct, or to and from the centre of action, whereas the former are lateral. It seems to me, that the resultant of two or more lines of force is in an apt condition for that action which may be considered as equivalent to a *lateral* vibration; whereas a uniform medium, like the æther, does not appear apt, or more apt than air or water.

The occurrence of a change at one end of a line of force easily suggests a consequent change at the other. The propagation of light, and therefore probably of all radiant action, occupies *time*; and, that a vibration of the line of force should account for the phænomena of radiation, it is necessary that such vibration should occupy time also. I am not aware whether there are any data by which it has been, or could be ascertained whether such a power as gravitation acts without occupying time, or whether lines of force being already in existence, such a lateral disturbance of them at one end as I have suggested above, would require time, or must of necessity be felt instantly at the other end.

As to that condition of the lines of force which represents the assumed high elasticity of the æther, it cannot in this respect be deficient: the question here seems rather to be, whether the lines are sluggish enough in their action to render them equivalent to the æther in respect of the time known experimentally to be occupied in the transmission of radiant force.

The æther is assumed as pervading all bodies as well as space: in the view now set forth, it is the forces of the atomic centres which pervade (and make) all bodies, and also penetrate all space. As regards space, the difference is, that the æther presents successive parts or centres of action, and the present supposition only lines of action; as regards matter, the difference is, that the æther lies between the particles and so carries on the vibrations, whilst as respects the supposition, it is by the lines of force between the centres of the particles that the vibration is continued. As to the difference in intensity of action within matter under the two views, I suppose it will be very difficult to draw any conclusion, for when we take the simplest state of common matter and that which most nearly causes it to approximate to the condition of the æther, namely the state of the rare gas, how soon do we find in its elasticity and the mutual repulsion of its particles, a departure from the law, that the action is inversely as the square of the distance!

And now, my dear Phillips, I must conclude. I do not think I should have allowed these notions to have escaped from me, had I not been led unawares, and without previous consideration, by the circumstances of the evening on which I had to appear suddenly and occupy the place of another. Now that I have put them on paper, I feel that I ought to have kept them much longer for study, consideration, and, perhaps final rejection; and it is only because they are sure to go abroad in one way or another, in consequence of their utterance on that evening, that I give them a shape, if shape it may be called, in this reply to your inquiry. One thing is certain, that any hypothetical view of radiation which is likely to be received or retained as satisfactory, must not much longer comprehend alone certain phænomena of light, but must include those of heat and of actinic influence also, and even the conjoined phænomena of sensible heat and chemical power produced by them. In this respect, a view, which is in some degree founded upon the ordinary forces

> of matter, may perhaps find a little consideration amongst the other views that will probably arise. I think it likely that I have made many mistakes in the preceding pages, for even to myself, my ideas on this point appear only as the shadow of a speculation, or as one of those impressions on the mind which are allowable for a time as guides to thought and research. He who labours in experimental inquiries knows how numerous these are, and how often their apparent fitness and beauty vanish before the progress and development of real natural truth."[2941]

Faraday's ideas were very influential. William Kingdon Clifford argued for a space theory of matter in the 1870's. Clifford speculated in the year of his death and of Einstein's birth, 1879, that light may be naught but flickering "space",

> "In order to explain the phenomena of light, it is not necessary to assume anything more than a periodical oscillation between two states at any given point of space."[2942]

Karl Pearson noted, as second editor and annotator of Clifford's *The Common Sense of the Exact Sciences* in 1884-1885,

> "The most notable physical quantities which vary with position and time are heat, light, and electro-magnetism. It is these that we ought peculiarly to consider when seeking for any physical changes, which may be due to changes in the curvature of space. If we suppose the boundary of any arbitrary figure in space to be distorted by the variation of space-curvature, there would, by analogy from one and two dimensions, be no change in the volume of the figure arising from such distortion. Further, if we *assume* as an axiom that space resists curvature with a resistance proportional to the change, we find that waves of 'space-displacement' are precisely similar to those of the elastic medium which we suppose to propagate light and heat. We also find that 'space-twist' is a quantity exactly corresponding to magnetic induction, and satisfying relations similar to those which hold for the magnetic field. It is a question whether physicists might not find it simpler to assume that space is capable of a varying curvature, and of a resistance to that variation, than to suppose the existence of a subtle medium pervading an invariable homaloidal space."[2943]

Clifford stated, in 1870, in his lecture, "On the Space Theory of Matter,"

> "RIEMANN has shown that as there are different kinds of lines and surfaces, so there are different kinds of space of three dimensions; and that we can only find out by experience to which of these kinds the space in which we live belongs. In particular, the axioms of plane geometry are true within the limits of experiment on the surface of a sheet of paper, and yet we know that the sheet is really covered with a number of small ridges and furrows, upon

which (the total curvature not being zero) these axioms are not true. Similarly, he says although the axioms of solid geometry are true within the limits of experiment for finite portions of our space, yet we have no reason to conclude that they are true for very small portions; and if any help can be got thereby for the explanation of physical phenomena, we may have reason to conclude that they are not true for very small portions of space.

I wish here to indicate a manner in which these speculations may be applied to the investigation of physical phenomena. I hold in fact

(1) That small portions of space *are* in fact of a nature analogous to little hills on a surface which is on the average flat; namely, that the ordinary laws of geometry are not valid in them.

(2) That this property of being curved or distorted is continually being passed on from one portion of space to another after the manner of a wave.

(3) That this variation of the curvature of space is what really happens in that phenomenon which we call the *motion of matter*, whether ponderable or ethereal.

(4) That in the physical world nothing else takes place but this variation, subject (possibly) to the law of continuity.

I am endeavouring in a general way to explain the laws of double refraction on this hypothesis, but have not yet arrived at any results sufficiently decisive to be communicated."[2944]

Clifford stated, in a work published posthumously in 1885, some six years after his death,

"§19. *On the Bending of Space*

The peculiar topic of this chapter has been position, position namely of a point P relative to a point A. This relative position led naturally to a consideration of the geometry of steps. I proceeded on the hypothesis that all position is relative, and therefore to be determined only by a stepping process. The relativity of position was a postulate deduced from the customary methods of determining position, such methods in fact always giving relative position. *Relativity of position is thus a postulate derived from experience*. The late Professor Clerk-Maxwell fully expressed the weight of this postulate in the following words:—

All our knowledge, both of time and place, is essentially relative. When a man has acquired the habit of putting words together, without troubling himself to form the thoughts which ought to correspond to them, it is easy for him to frame an antithesis between this relative knowledge and a so-called absolute knowledge, and to point out our ignorance of the absolute position of a point as an instance of the limitation of our faculties. Any one, however, who will try to imagine the state of a mind conscious of knowing the absolute position of a point will ever after be content with our relative knowledge.[2945]

It is of such great value to ascertain how far we can be certain of the truth of our postulates in the exact sciences that I shall ask the reader to return to our conception of position albeit from a somewhat different standpoint. I shall even ask him to attempt an examination of that state of mind which Professor Clerk-Maxwell hinted at in his last sentence.

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But we may press our analogy a step further, and ask, since our hypothetical worm and fish might very readily attribute the effects of changes in the bending of their spaces to changes in their own physical condition, whether we may not in like fashion be treating merely as physical variations effects which are really due to changes in the curvature of our space; whether, in fact, some or all of those causes which we term physical may not be due to the geometrical construction of our space. There are three kinds of variation in the curvature of our space which we ought to consider as within the range of possibility.

(i) Our space is perhaps really possessed of a curvature varying from point to point, which we fail to appreciate because we are acquainted with only a small portion of space, or because we disguise its small variations under changes in our physical condition which we do not connect with our change of position. The mind that could recognize this varying curvature might be assumed to know the absolute position of a point. For such a mind the postulate of the relativity of position would cease to have a meaning. It does not seem so hard to conceive such a state of mind as the late Professor Clerk-Maxwell would have had us believe. It would be one capable of distinguishing those so-called physical changes which are really geometrical or due to a change of position in space.

(ii) Our space may be really same (of equal curvature), but its degree of curvature may change as a whole with the time. In this way our geometry based on the sameness of space would still hold good for all parts of space, but the change of curvature might produce in space a succession of apparent physical changes.

(iii) We may conceive our space to have everywhere a nearly uniform curvature, but that slight variations of the curvature may occur from point to point, and themselves vary with the time. These variations of the curvature with the time may produce effects which we not unnaturally attribute to physical causes independent of the geometry of our space. We might even go so far as to assign to this variation of the curvature of space 'what really happens in that phenomenon which we term the motion of matter.'

We have introduced these considerations as to the nature of our space to bring home to the reader the character of the postulates we make in the exact sciences. These postulates are *not*, as too often assumed, necessary and universal truths; they are merely axioms based on our experience of a certain limited region. Just as in any branch of physical inquiry we start by making experiments, and basing on our experiments a set of axioms which form the foundation of an exact science, so in geometry our axioms are really, although less obviously, the result of experience. On this ground geometry has been properly termed at the commencement of Chapter II a *physical* science. The danger of asserting dogmatically that an axiom based on the experience of a limited region holds universally will now be to some extent apparent to the reader. It may lead us to entirely overlook, or when suggested at once reject, a possible explanation of phenomena. The hypotheses that space is not homaloidal, and again, that its geometrical character may change with the time, may or may not be destined to play a great part in the physics of the future; yet we cannot refuse to consider them as possible explanations of physical phenomena, because they may be opposed to the popular dogmatic belief in the universality of certain geometrical axioms—a belief which has arisen from centuries of indiscriminating worship of the genius of Euclid."[2946]

14.5 Mach's Principle

The pantheistic Cabalist Henry More (who was also inspired by Aristotle and who inspired John Locke, Isaac Newton and Samuel Clarke) wrote that absolute space is God, as proved by the thought experiment of the hypothetical annihilation of all matter,

"But if this will not satisfy, 'tis no detriment to our cause: For if, after the removal of *corporeal Matter* out of the world, there will be still *Space* and *Distance* in which this very Matter, while it was there, was also conceiv'd to lie, and this *distant Space* cannot but be something, and yet not corporeal, because neither impenetrable nor tangible; it must of necessity be a Substance Incorporeal necessarily and eternally existent of it self: which the clearer *Idea* of a *Being absolutely perfect* will more fully and punctually inform us to be the *Self-subsisting God*."[2947]

John Locke raised the issue in his essay *Concerning Human Understanding*, Chapter 13, Section 22, which would lead Berkeley to "Mach's Principle" some 150 years before Mach. Locke wrote,

"22. *The power of annihilation proves a vacuum*. Farther, those who assert the impossibility of space existing without matter, must not only make body infinite, but must also deny a power in God to annihilate any part of matter. No one, I suppose, will deny that God can put an end to all motion that is in matter, and fix all the bodies of the universe in a perfect quiet and rest, and continue them so long as he pleases. Whoever then will allow that God can, during such a general rest, *annihilate* either this book or the body of him that reads it, must necessarily admit the possibility of a vacuum. For, it is evident that the space that was filled by the parts of the annihilated body will still remain, and be a space without body. For the circumambient bodies being in perfect rest, are a wall of adamant, and in that state make it a perfect impossibility for any other body to get into that space. And indeed the necessary motion of one particle of matter into the place from whence another particle of matter is removed, is but a consequence from the supposition of plenitude; which will therefore need some better proof than a supposed matter of fact, which experiment can never make out;—our own clear and distinct ideas plainly satisfying us, that there is no necessary connexion between space and solidity, since we can conceive the one without the other. And those who dispute for or against a vacuum, do thereby confess they have distinct *ideas* of vacuum and plenum, i.e. that they have an idea of extension void of solidity, though they deny its *existence*; or else they dispute about nothing at all. For they who so much alter the signification of words, as to call extension body, and consequently make the whole essence of body to be nothing but pure extension without solidity, must talk absurdly whenever they speak of *vacuum*; since it is impossible for extension to be without extension. For *vacuum*, whether we affirm or deny its existence, signifies space without body; whose very existence no one can deny to be possible, who will not make matter infinite, and take from God a power to annihilate any particle of it."

Locke's idea was pursued by Isaac Newton,[2948] Samuel Clarke,[2949] and Carl Neumann, who stated in 1869,

"This seems to be the right place for an observation which forces itself upon us and from which it clearly follows how unbearable are the contradictions that arise when motion is conceived as something relative rather than something absolute. Let us assume that among the stars there is one which is composed of fluid matter and is somewhat similar to our terrestrial globe and that it is rotating around an axis that passes through its center. As a result of such a motion, and due to the resulting centrifugal forces, this star would take on the shape of a flattened ellipsoid. We now ask: What shape will this star assume if all remaining heavenly bodies are suddenly annihilated (turned into nothing)? These centrifugal forces are dependent only on the state of the star itself; they are totally independent of the remaining heavenly bodies. Consequently, this is our answer: These centrifugal forces and the spherical ellipsoidal form dependent on them will persist regardless of whether the remaining heavenly bodies continue to exist or suddenly disappear."[2950]

Berkeley, Mach and others opposed the ontological supposition that space is an entity unto itself and that inertia would exist without other matter. Des Cartes asserted that extension is a property of matter, and only by mental abstraction becomes "space". Leibnitz' monadistic philosophy emphasized that, "without matter no space".[2951]

Berkeley was one of many who argued against Newtonian absolutism. From Berkeley's *Principles of Human Knowledge* of 1710, "97. Beside the external existence of the objects of perception, another great source of errors and difficulties with regard to ideal knowledge is the doctrine of *abstract ideas*, such as it hath been set forth in the Introduction. The plainest things in the world, those we are most intimately acquainted with and perfectly know, when they are considered in an abstract way, appear strangely difficult and incomprehensible. Time, place, and motion, taken in particular or concrete, are what everybody knows, but, having passed through the hands of a metaphysician, they become too abstract and fine to be apprehended by men of ordinary sense. Bid your servant meet you at such a *time* in such a *place*, and he shall never stay to deliberate on the meaning of those words; in conceiving that particular time and place, or the motion by which he is to get thither, he finds not the least difficulty. But if *time* be taken exclusive of all those particular actions and ideas that diversify the day, merely for the continuation of existence or duration in abstract, then it will perhaps gravel even a philosopher to comprehend it.

98. For my own part, whenever I attempt to frame a simple idea of *time*, abstracted from the succession of ideas in my mind, which flows uniformly and is participated by all beings, I am lost and embrangled in inextricable difficulties. I have no notion of it at all, only I hear others say it is infinitely divisible, and speak of it in such a manner as leads me to entertain odd thoughts of my existence; since that doctrine lays one under an absolute necessity of thinking, either that he passes away innumerable ages without a thought, or else that he is annihilated every moment of his life, both which seem equally absurd. Time therefore being nothing, abstracted from the sucession of ideas in our minds, it follows that the duration of any finite spirit must be estimated by the number of ideas or actions succeeding each other in that same spirit or mind. Hence, it is a plain consequence that the soul always thinks; and in truth whoever shall go about to divide in his thoughts, or abstract the *existence* of a spirit from its *cogitation*, will, I believe, find it no easy task.

99. So likewise when we attempt to abstract extension and motion from all other qualities, and consider them by themselves, we presently lose sight of them, and run into great extravagances. All which depend on a twofold abstraction; first, it is supposed that extension, for example, may be abstracted from all other sensible qualities; and secondly, that the entity of extension may be abstracted from its being perceived. But, whoever shall reflect, and take care to understand what he says, will, if I mistake not, acknowledge that all sensible qualities are alike *sensations* and alike *real*; that where the extension is, there is the colour, too, *i.e.*, in his mind, and that their archetypes can exist only in some other *mind*; and that the objects of sense are nothing but those sensations combined, blended, or (if one may so speak) concreted together; none of all which can be supposed to exist unperceived.

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110. The best key for the aforesaid analogy or natural Science will be

easily acknowledged to be a certain celebrated Treatise of *Mechanics*. In the entrance of which justly admired treatise, Time, Space, and Motion are distinguished into *absolute* and *relative*, *true* and *apparent*, *mathematical* and *vulgar*; which distinction, as it is at large explained by the author, does suppose these quantities to have an existence without the mind; and that they are ordinarily conceived with relation to sensible things, to which nevertheless in their own nature they bear no relation at all.

111. As for *Time*, as it is there taken in an absolute or abstracted sense, for the duration or perseverance of the existence of things, I have nothing more to add concerning it after what has been already said on that subject. [*Sect*. 97 and 98] For the rest, this celebrated author holds there is an *absolute Space*, which, being unperceivable to sense, remains in itself similar and immovable; and relative space to be the measure thereof, which, being movable and defined by its situation in respect of sensible bodies, is vulgarly taken for immovable space. *Place* he defines to be that part of space which is occupied by any body; and according as the space is absolute or relative so also is the place. *Absolute Motion* is said to be the translation of a body from absolute place to absolute place, as relative motion is from one relative place to another. And, because the parts of absolute space do not fall under our senses, instead of them we are obliged to use their sensible measures, and so define both place and motion with respect to bodies which we regard as immovable. But, it is said in philosophical matters we must abstract from our senses, since it may be that none of those bodies which seem to be quiescent are truly so, and the same thing which is moved relatively may be really at rest; as likewise one and the same body may be in relative rest and motion, or even moved with contrary relative motions at the same time, according as its place is variously defined. All which ambiguity is to be found in the apparent motions, but not at all in the true or absolute, which should therefore be alone regarded in philosophy. And the true as we are told are distinguished from apparent or relative motions by the following properties.—First, in true or absolute motion all parts which preserve the same position with respect of the whole, partake of the motions of the whole. Secondly, the place being moved, that which is placed therein is also moved; so that a body moving in a place which is in motion doth participate the motion of its place. Thirdly, true motion is never generated or changed otherwise than by force impressed on the body itself. Fourthly, true motion is always changed by force impressed on the body moved. Fifthly, in circular motion barely relative there is no centrifugal force, which, nevertheless, in that which is true or absolute, is proportional to the quantity of motion.

112. But, notwithstanding what has been said, I must confess it does not appear to me that there can be any motion other than *relative*; so that to conceive motion there must be at least conceived two bodies, whereof the distance or position in regard to each other is varied. Hence, if there was one only body in being it could not possibly be moved. This seems evident, in that the idea I have of motion doth necessarily include relation.

113. But, though in every motion it be necessary to conceive more bodies than one, yet it may be that one only is moved, namely, that on which the force causing the change in the distance or situation of the bodies, is impressed. For, however some may define relative motion, so as to term that body *moved* which changes its distance from some other body, whether the force or action causing that change were impressed on it or no, yet as relative motion is that which is perceived by sense, and regarded in the ordinary affairs of life, it should seem that every man of common sense knows what it is as well as the best philosopher. Now, I ask any one whether, in his sense of motion as he walks along the streets, the stones he passes over may be said to *move*, because they change distance with his feet? To me it appears that though motion includes a relation of one thing to another, yet it is not necessary that each term of the relation be denominated from it. As a man may think of somewhat which does not think, so a body may be moved to or from another body which is not therefore itself in motion.

114. As the place happens to be variously defined, the motion which is related to it varies. A man in a ship may be said to be quiescent with relation to the sides of the vessel, and yet move with relation to the land. Or he may move eastward in respect of the one, and westward in respect of the other. In the common affairs of life men never go beyond the earth to define the place of any body; and what is quiescent in respect of that is accounted *absolutely* to be so. But philosophers, who have a greater extent of thought, and juster notions of the system of things, discover even the earth itself to be moved. In order therefore to fix their notions they seem to conceive the corporeal world as finite, and the utmost unmoved walls or shell thereof to be the place whereby they estimate true motions. If we sound our own conceptions, I believe we may find all the absolute motion we can frame an idea of to be at bottom no other than relative motion thus defined. For, as hath been already observed, absolute motion, exclusive of all external relation, is incomprehensible; and to this kind of relative motion all the above-mentioned properties, causes, and effects ascribed to absolute motion will, if I mistake not, be found to agree. As to what is said of the centrifugal force, that it does not at all belong to circular relative motion, I do not see how this follows from the experiment which is brought to prove it. See *Philosophiae Naturalis Principia Mathematica*, *in Schol*. *Def. VIII*. For the water in the vessel at that time wherein it is said to have the greatest relative circular motion, hath, I think, no motion at all; as is plain from the foregoing section.

115. For, to denominate a body *moved* it is requisite, first, that it change its distance or situation with regard to some other body; and secondly, that the force occasioning that change be applied to it. If either of these be wanting, I do not think that, agreeably to the sense of mankind, or the propriety of language, a body can be said to be in motion. I grant indeed that it is possible for us to think a body which we see change its distance from some other to be moved, though it have no force applied to it (in which sense there may be apparent motion), but then it is because the force causing the

change of distance is imagined by us to be applied or impressed on that body thought to move; which indeed shews we are capable of mistaking a thing to be in motion which is not, and that is all.

116. From what has been said it follows that the philosophic consideration of motion does not imply the being of an *absolute Space*, distinct from that which is perceived by sense and related bodies; which that it cannot exist without the mind is clear upon the same principles that demonstrate the like of all other objects of sense. And perhaps, if we inquire narrowly, we shall find we cannot even frame an idea of *pure Space* exclusive of all body. This I must confess seems impossible, as being a most abstract idea. When I excite a motion in some part of my body, if it be free or without resistance, I say there is *Space*; but if I find a resistance, then I say there is *Body*; and in proportion as the resistance to motion is lesser or greater, I say the space is more or less *pure*. So that when I speak of pure or empty space, it is not to be supposed that the word 'space' stands for an idea distinct from or conceivable without body and motion—though indeed we are apt to think every noun substantive stands for a distinct idea that may be separated from all others; which has occasioned infinite mistakes. When, therefore, supposing all the world to be annihilated besides my own body, I say there still remains *pure Space*, thereby nothing else is meant but only that I conceive it possible for the limbs of my body to be moved on all sides without the least resistance, but if that, too, were annihilated then there could be no motion, and consequently no Space. Some, perhaps, may think the sense of seeing doth furnish them with the idea of pure space; but it is plain from what we have elsewhere shewn, that the ideas of space and distance are not obtained by that sense. See the Essay concerning Vision."

Berkeley presented a long and detailed argument against Newton's bucket experiment to detect absolute motion[2952] in Berkeley's *De Motu* of 1721 in sections 53-66, iterating what later came to be known as "Mach's Principle".

Newton wrote in the *Principia*, Book I, Definition VIII, Scholium, *inter alia*,

"The Effects which distinguish absolute from relative motion are, the forces of receding from the axe of circular motion. For there are no such forces in a circular motion purely relative, but in a true and absolute circular motion, they are greater or less, according to the quantity of the motion. If a vessel, hung by a long cord, is so often turned about that the cord is strongly twisted, then fill'd with water, and held at rest together with the water; after by the sudden action of another force, it is whirl'd about the contrary way, and while the cord is untwisting it self, the vessel continues for some time in this motion; the surface of the water will at first be plain, as before the vessel began to move: but the vessel, by gradually communicating its motion to the water, will make it begin sensibly to revolve, and recede by little and little from the middle, and ascend to the sides of the vessel, forming itself into a concave figure, (as I have experienced) and the swifter the motion becomes, the higher will the water rise, till at last, performing its revolutions in the same times with the vessel, it becomes relatively at rest in it. This ascent of the water shows its endeavour to recede from the axe of its motion; and the true and absolute circular motion of the water, which is here directly contrary to the relative, discovers it self, and may be measured by this endeavour. At first, when the relative motion of the water in the vessel was greatest, it produc'd no endeavour to recede from the axe: the water shew'd no tendency to the circumference, nor any ascent towards the sides of the vessel, but remain'd of a plain surface, and therefore its True circular motion had not yet begun. But afterwards, when the relative motion of the water had decreas'd, the ascent thereof towards the sides of the vessel, prov'd its endeavour to recede from the axe; and this endeavour shew'd the real circular motion of the water perpetually increasing, till it had acquir'd its greatest quantity, when the water rested relatively in the vessel. And therefore this endeavour does not depend upon any translation of the water in respect of the ambient bodies, nor can true circular motion be defin'd by such translation. There is only one real circular motion of any one revolving body, corresponding to only one power of endeavouring to recede from its axe of motion, as its proper and adequate effect: but relative motions in one and the same body are innumerable, according to the various relations it bears to external bodies, and like other relations, are altogether destitute of any real effect, any otherwise than they may perhaps participate of that one only true motion. And therefore in their system who suppose that our heavens, revolving below the sphere of the fixt Stars, carry the Planets along with them; the several parts of those heavens, and the Planets, which are indeed relatively at rest in their heavens, do yet really move. For they change their position one to another (which never happens to bodies truly at rest) and being carried together with their heavens, participate of their motions, and as parts of revolving wholes, endeavour to recede from the axe of their motions."[2953]

Berkeley objected to Newton's argument, and wrote, *inter alia*,

"Therefore we must say that the water forced round in the bucket rises to the sides of the vessel, because when new forces are applied in the direction of the tangent to any particle of water, in the same instant new equal centripetal forces are not applied. From which experiment it in no way follows that absolute circular motion is necessarily recognized by the forces of retirement from the axis of motion. [***] [I]t would be enough to bring in, instead of absolute space, relative space as confined to the heavens of the fixed stars, considered as at rest. But motion and rest marked out by such relative space can conveniently be substituted in place of the absolutes, which cannot be distinguished from them by any mark."[2954]

Boscovich argued in the second supplement to his *A Theory of Natural Philosophy*, Section 20, "20. When either objects external to us, or our organs change their modes of existence in such a way that that first equality or similitude does not remain constant, then indeed the ideas are altered, & there is a feeling of change; but the ideas are the same exactly, whether the external objects suffer the change, or our organs, or both of them unequally. In every case our ideas refer to the difference between the new state & the old, & not to the absolute change, which does not come within the scope of our senses. Thus, whether the stars move round the Earth, or the Earth & ourselves move in the opposite direction round them, the ideas are the same, & there is the same sensation. We can never perceive absolute changes; we can only perceive the difference from the former configuration that has arisen. Further, when there is nothing at hand to warn us as to the change of our organs, then indeed we shall count ourselves to have been unmoved, owing to a general prejudice for counting as nothing those things that are nothing in our mind; for we cannot know of this change, & we attribute the whole of the change to objects situated outside of ourselves. In such manner any one would be mistaken in thinking, when on board ship, that he himself was motionless, while the shore, the hills & even the sea were in motion."[2955]

In 1881, Johann Bernhard Stallo provided us with a good history which fills in the gaps in the evolution of "Mach's Principle" between Berkeley and Mach,

"Now, in any discussion of the operations of thought, it is of the utmost importance to bear in mind the following irrefragable truths, some of which—although all of them seem to be obvious—have not been clearly apprehended until very recent times:

1. Thought deals, not with things as they are, or are supposed to be, in themselves, but with our mental representations of them. Its elements are, not pure objects, but their intellectual counterparts. What is present in the mind in the act of thought is never a thing, but always a state or states of consciousness. However much, and in whatever sense, it may be contended that the intellect and its object are both real and distinct entities, it can not for a moment be denied that the object, of which the intellect has cognizance, is a synthesis of objective and subjective elements, and is thus primarily, in the very act of its apprehension and to the full extant of its cognizable existence, affected by the determinations of the cognizing faculty. Whenever, therefore, we speak of a thing, or a property of a thing, it must be understood that we mean a product of two factors neither of which is capable of being apprehended by itself. In this sense all knowledge is said to be relative.

2. Objects are known only through their relations to other objects. They have, and can have, no properties, and their concepts can include no attributes, save these relations, or rather, our mental representations of them. Indeed, an object can not be known or conceived otherwise than as a complex of such relations. In mathematical phrase: things and their properties are known only as functions of other things and properties. In this

sense, also, relativity is a necessary predicate of all objects of cognition.

3. A particular operation of thought never involves the entire complement of the known or knowable properties of a given object, but only such of them as belong to a definite class of relations. In mechanics, for instance, a body is considered simply as a mass of determinate weight and volume (and in some cases figure), without reference to its other physical or chemical properties. In like manner each of the several other departments of knowledge effects a classification of objects upon its own peculiar principles, thereby giving rise to different series of concepts in which each concept represents that attribute or group of attributes—that aspect of the object—which it is necessary, in view of the question in hand, to bring into view. Our thoughts of things are thus, in the language of Leibnitz, adopted by Sir William Hamilton, and after him by Herbert Spencer, *symbolical,* not (or, at least, not only) because a complete mental representation of the properties of an object is precluded by their number and the incapacity of the mind to hold them in simultaneous grasp, but because many (and in most cases the greater part) of them are irrelevant to the mental operation in progress.

CHARACTER AND ORIGIN OF THE MECHANICAL THEORY (CONTINUED).—ITS EXEMPLIFICATION OF THE FOURTH RADICAL ERROR OF METAPHYSICS.

THE reality of all things which are, or can be, objects of cognition, is founded upon, or, rather, consists in, their mutual relations. A thing in and by itself can be neither apprehended nor conceived; its existence is no more a presentation of sense than a deliverance of thought. Things are known to us solely through their properties; and the properties of things are nothing else than their interactions and mutual relations. 'Every property or quality of a thing,' says Helmholtz [*Footnote:* Die neueren Fortschritte in der Theorie des Sehens. Pop. Wiss. Vortraege, ii, 55 *seq*.] (speaking of the inveterate prejudice according to which the qualities of things must be analogous to, or identical with, our perceptions of them), 'is in reality nothing but its capability of producing certain effects on other things. The effect occurs either between like parts of the same body so as to produce differences of aggregation, or it proceeds from one body to another, as in the case of chemical reactions; or the effects are upon our organs of sense and manifest themselves as sensations such as those with which we are here concerned (the sensations of sight). Such an effect we call a 'property,' its reagent being understood without being expressly mentioned. Thus we speak of the 'solubility' of a substance, meaning its behavior toward water; we speak of its 'weight,' meaning its attraction to the earth; and we may justly call a substance 'blue' under the tacit assumption that we are only speaking of its action upon a normal eye. But, if what we call a property always implies a relation between two things, then a property or quality can never depend upon the nature of one agent alone, but exists only in relation to and dependence on the nature of some second object acted upon. Hence, there is really no sense in talking of properties of light which belong to it absolutely, independently of all other objects, and which are supposed to be representable in the sensations of the human eye. The notion of such properties is a contradiction in itself. They can not possibly exist, and therefore we can not expect to find any coincidence of our sensations of color with qualities of light.'

The truth which underlies these sentences is of such transcendent importance that it is hardly possible to be too emphatic in its statement, or too profuse in its illustration. The real existence of things is coextensive with their qualitative and quantitative determinations. And both are in their nature relations, quality resulting from mutual action, and quantity being simply a ratio between terms neither of which is absolute. Every objectively real thing is thus a term in numberless series of mutual implications, and forms of reality beyond these implications are as unknown to experience as to thought. There is no absolute material quality, no absolute material substance, no absolute physical unit, no absolutely simple physical entity, no absolute physical constant, no absolute standard, either of quantity or quality, no absolute motion, no absolute rest, no absolute time, no absolute space. There is no form of material existence which is either its own support or its own measure, and which abides, either quantitatively or qualitatively, otherwise than in perpetual change, in an unceasing flow of mutations. An object is large only as compared with another which, as a term of this comparison, is small, but which, in comparison with a third object, may be indefinitely large; and the comparison which determines the magnitude of objects is between its terms alone, and not between any or all of its terms and an absolute standard. An object is hard as compared with another which is soft, but which, in turn, may be contrasted with a third still softer; and, again, there is no standard object which is either absolutely hard or absolutely soft. A body is simple as compared with the compound into which it enters as a constituent; but there is and can be no physically real thing which is absolutely simple [*Footnote:* One of the most noteworthy specimens of ontological reasoning is the argument which infers the existence of absolutely simple substances from the existence of compound substances. Leibnitz places this argument at the head of his 'Monadology.' '*Necess est*,' he says, '*dari substantias simplices quia dantur compositæ; neque enim compositum est nisi aggregatum simplicium*.' (Leibnitii, Opera omnia, ed. Dutens, t. ii., p. 21.) But the enthymeme is obviously a vicious paralogism—a fallacy of the class known in logic as fallacies of suppressed relative. The existence of a compound substance certainly proves the existence of component parts which, *relatively to this substance*, are simple. But it proves nothing whatever as to the simplicity of these parts in themselves.]

It may be observed, in this connection, that not only the law of causality, the conservation of energy, and the indestructibility of matter, so called, have their root in the relativity of all objective reality—being, indeed, simply different aspects of this relativity—but that Newton's first and third laws of motion, as well as all laws of least action in mechanics (including Gauss's law of movement under least constraint), are but corollaries from the same principle. And the fact that everything is, in its manifest existence, but a group of relations and reactions at once accounts for Nature's inherent teleology.

Although the truth that all our knowledge of obective reality depends upon the establishment or recognition of relations is sufficiently evident and has been often proclaimed, it has thus far been almost wholly ignored by men of science as well as by metaphysicians. It is to this day assumed by physicists and mathematicians, no less than by ontologists, that all reality is in its last elements absolute. And this assumption is all the more strenuously insisted on by those whose scientific creed begins with the proposition that all our knowledge of physical things is derived from experience. Thus the mathematician, who fully recognizes the validity of this proposition and at the same time concedes that we have, and can have, no actual knowledge of bodies at rest or in motion, except in relation to other bodies, nevertheless declares that rest and motion are real only in so far as they and their elements, space and time, are absolute. The physicist reminds us at every step that in the field of his investigations there are no *a priori* truths and that nothing is known of the world of matter save what has been ascertained by observation and experiment; he then announces as the uniform result of his observations and experiments, that all forms of material existence are complex and variable; and yet he avers that not merely the laws of their variation are constant, but that the real constituents of the material world are absolutely simple, invariable, individual things.

The assumption that all physical reality is in its last elements absolute—that the material universe is an aggregate of absolutely constant physical units which in themselves are absolutely at rest, but whose motion, however induced, is measurable in terms of absolute space and absolute time—is obviously the true logical basis of the atomo-mechanical theory. And this assumption is identical with that which lies at the root of all metaphysical systems, with the single difference that in some of these systems the physical substratum of motion (termed the “substance” of things) is not specialized into individual atoms.

To show how irrepressibly the ontological prejudice, that nothing is physically real which is not absolute, has asserted itself in science during the last three centuries, I propose briefly to review the doctrines of some of the most eminent mathematicians and physicists respecting space and motion (and, incidentally, time), beginning with those of Descartes.

In the introductory parts of his Principia, Descartes states in the most explicit terms that space and motion are essentially relative. ‘In order that the place [of a body] may be determined,’ he says, [*Footnote:* Princ. ii, § 18.] ‘we must refer to other bodies which we may regard as immovable, and accordingly as we refer to different bodies it can be said that the same thing does, and does not, change its place. Thus, when a ship is carried along at sea, he who sits at the stern remains always at the same place in reference to the parts of the ship among which he retains the same position; but he continually changes his place in reference to the shores. . . . And besides, if we allow that the earth moves and proceeds—precisely as far from west to east as the ship meanwhile is carried from east to west—we shall say again that he who sits at the stern does not move his place, because we determine it with reference to some immovable points in the heavens. But, if finally we concede that no truly immovable points are to be found in the universe, as I shall hereafter show is probable, our conclusion will be that there is nothing which has a fixed place except so far as it is determined in thought.' [*Footnote:* The illustration of the relativity of motion by the motion of a ship is of constant recurrence whenever reference is had to the question discussed in the text. Cf. Leibnitz, Opp. ed. Erdmann, p. 604; Newton, Princ., Def. viii, Schol. 3; Euler, Theoria Motûs Corporum Solidorum, vol. i, 9, 10; Berkeley, Principles of Human Knowledge, § 114; Kant, Metaphysische Aufansgruende der Naturwissenschaft, Phor. Grundsatz I; Cournot, De l'Enchainement, etc., vol. i, p. 56; Herbert Spencer, First Principles, chapter iii, § 17, etc, etc.]

Statements to the same effect are found in various other parts of the same book. [*Footnote:* E. g., Princ., ii, 24, 25, 29, etc.] And of space Descartes does not hesitate to say that is really nothing in itself, and that 'void space' is a contradiction in terms—that, as Sir John Herschel puts it, [*Footnote:* Familiar Lectures, p. 445.] 'if it were not for the foot-rule between them, the two ends of it would be in the same place.' But, in the further progress of his discussions, having meanwhile declared that God always conserves in the universe the same quantity of motion, he all at once takes it for granted [*Footnote:* Princ., ii, §§ 37-39.] that motion and space are absolute and therefore real entities.

This inconsistency of Descartes is severely censured by Leibnitz. 'It follows,' says Leibnitz, [*Footnote:* Leibn., Opp. Math., ed. Gerhardt, sect. II, vol. II, p. 247.] 'that motion is nothing but a change of place, and thus, so far as phenomena are concerned, consists in a mere relation. This Cartesius also acknowledged; but in deducing his consequences he forgot his own definition and framed his laws of motion *as though motion were something real and absolute*.' As will be noticed, Leibnitz here assumes, as a matter of course, that what is real is also absolute. In view of this it is hardly surprising that he, too, falls into the same inconsistency with which he charges Descartes, and, in his letters to Clarke, speaks of 'absolutely immovable space' and an 'absolutely veritable motion of bodies.' [*Footnote:* Opp. Ed. Erdmann, pp. 766, 770.]

Newton, in the great Scholium to the last of the 'Definitions' prefixed to his Principia, sharply distinguishes between absolute and relative time and motion. 'Absolute and mathematical time,' he says, [*Footnote:* Princ. (Ed. Le Seur & Jacq.), p. 8.'] 'in itself and in its nature without relation to anything external, flows equally and is otherwise called duration; relative, apparent and vulgar time is any sensible and extrinsic, accurate or unequal measure of duration by motion which is ordinarily taken for true time. . . . Absolute is distinguished from relative time in astronomy by the equation of vulgar time. For the natural days, which are vulgarly taken in the measurement of time as equal, are unequal. . . . *It may be that there is no equable motion by which time is accurately measured*.' [*Footnote: L. c*., p. 10.]

'Absolute space, in its nature without relation to anything external, always remains similar and immovable; of this (absolute space) relative space is any movable measure or dimension which is sensibly defined by its place in reference to bodies, and is vulgarly taken for immovable space. . . [*Footnote: L. c*., p. 9.] We define all places by the distances of things from some [given] body which we take as immovable. . . . *It may be that there is no body truly at rest to which places and motions are to be referred*.' [*Footnote:* Ib., p. 10.]

Absolute motion, according to Newton, is 'the translation of a body from one absolute place to another,' and relative motion 'the translation of a body from one relative place to another. . . . Absolute rest and motion are distinguished from relative rest and motion by their properties and by their causes and effects. It is the property of rest that bodies truly at rest are at rest in respect to each other. Hence, while it is possible that in the regions of the fixed stars, or far beyond them, there is some body absolutely at rest, it is nevertheless impossible to know from the relative places of bodies in our regions, whether any such distant body persists in the given position, and therefore true rest can not be defined from the mutual position of these' [i. e., the bodies in our regions]. . . . 'It is the property of motion that the parts which retain their given positions to the wholes participate in their motion. For all the parts of rotating bodies tend to recede from the axis of motion, and the impetus of the moving bodies arises from the impetus of the parts. Hence, when the surrounding bodies move, those which move within them are relatively at rest. *And for this reason true and absolute motion, can not be defined by their translation from the vicinity of bodies which are looked upon as being at rest*. . . . [*Footnote:* Ib., p. 10, 11.] The causes by which true and relative motions are distinguished from each other are the forces impressed upon bodies for the generation of motion. True motion is generated or changed solely by the forces impressed upon the body moved; but relative motion may be generated and changed without the action of forces upon it. For it is sufficient that forces are impressed upon other bodies to which reference is had, so that by their giving way a change is effected in the relation in which the relative motion or rest of the body consists. . . . [*Footnote: L. c*., p. 11.] The effects by which absolute and relative motion are mutually distinguished are the forces by which bodies recede from the axis of circular motion. For in purely relative circular motion these forces are null, while in true and absolute motion they are greater or less according to the quantity of motion.' [*Footnote: Ib*.]

It is apparent that in all these definitions Newton, like Descartes and Leibnitz, assumes real motion to be absolute, and that he takes the terms *relative motion* and *apparent motion* to be strictly synonymous, notwithstanding his express admission (in the passages which I have italicized) that in fact there may be neither absolute time nor absolute space. That admission naturally leads to the further admission that there may in fact be no absolute motion; but from this Newton recoils, resorting to the expedient of trying to find tenable ground for the distinction between absolute and relative motion, despite the possible nonexistence of absolute time and space, in what he calls their respective causes and effects. But these causes and effects serve to distinguish, not relative from absolute change of position, but simply change of position in one body with reference to another from simultaneous changes of position in both with reference to a third.

Newton's doctrine is pushed to its last consequences by Leonhard Euler. In the first chapter of his 'Theory of the Motion of Solid or Rigid Bodies,' Euler begins with the emphatic declaration that rest and motion, so far as they are known to sensible experience, are purely relative. After referring to the typical case of the navigator in his ship, he proceeds: [*Footnote:* Theoria motûs Corp. Sol, etc., cap. i, explic. 2.] 'The notion of rest here spoken of, therefore, is one of relations, inasmuch as it is not derived solely from the condition of the point O to which it is attributed, but from a comparison with some other body A . . . . And hence it appears at once that the same body which is at rest with respect to the body A is in various motion with respect to other bodies. . . . What has been said of relative rest may be readily applied to relative motion; for when a point O retains its place with respect to a body A, it is said to be relatively at rest, and, when it continually changes that place, it is said to be relatively in motion. . . . [*Footnote: Ib*., p. 7.] *Therefore motion and rest are distinguished merely in name and are not opposed to each other in fact, inasmuch as both may at the same time be attributed to the same point, accordingly as it is referred to different bodies. Nor does motion differ from rest otherwise than as one motion differs from another*.' [*Footnote: Ib*., p. 8.]

After thus insisting upon the essential relativity of rest and motion, Euler proceeds, in the second chapter. 'On the Internal Principles of Motion,' to consider the question whether or not rest and motion are predicable of a body without reference to other bodies. To this question he unhesitatingly gives an affirmative answer, holding it to be axiomatic that 'every body, even without respect to other bodies, is either at rest or in motion, i. e., is either absolutely at rest or absolutely in motion. . . . [*Footnote: Omne corpus, etiam sine respectu ad alia corpora, vel quiescit vel movetur, hoc est, vel absolute quiescit, vel absolute movetur*.' *lb.,* p. 30 (cap. ii, axioma 7).] 'Thus far,' he explains, 'following the senses, we have not recognized any other motion or rest than that with respect to other bodies, whence we have called both motion and rest relative. But, if we now mentally take away all bodies but one, and if thus the relation by which we have hitherto distinguished its rest and motion is withdrawn, it will first be asked whether or not the conclusion respecting the rest or motion of the remaining body still stands. For, if this conclusion can be drawn only from a comparison of the place of the body in question with that of other bodies, it follows that, when these bodies are gone, the conclusion must go with them. *But*, *albeit we do not know of the rest or motion of a body except from its relation to other bodies*, *it is nevertheless not to be concluded that these things* (*rest and motion*) *are nothing in themselves but a mere relation established by the intellect*, *and that there is nothing inherent in the bodies themselves which corresponds to our ideas of rest and motion.* For, although we are unable to know quantity otherwise than by comparison, yet, when the things with which we instituted the comparison are gone, there is still left in the body *the fundamentum quantitatis*, as it were; for, if it were extended or contracted, such extension or contraction would have to be taken as a true change. Thus, if but one body existed, we should have to say that it was either in motion or at rest, inasmuch as it could not be taken as being both or neither. *Whence I conclude that rest and motion are not merely ideal things, born from comparison alone, so that there would be nothing inherent in the body corresponding to them*, but that it may be justly asked in respect to a solitary body whether it is in motion or at rest. . . . Inasmuch, therefore, as we can justly ask respecting a single body itself, without reference to other bodies, or under the supposition that they are annihilated, whether it is at rest or in motion, we must necessarily take one or the other alternative. But what this rest or motion will be, in view of the fact that there is here no change of place with respect to other bodies, we can not even think without admitting an absolute space in which our body occupies some given space whence it can pass to other places.' [*Footnote:* Theoria motûs, etc., p. 31.] Accordingly Euler most strenuously insists on the necessity of postulating an absolute, immovable space. 'Whoever denies absolute space,' he says, 'falls into the gravest perplexities. Since he is constrained to reject absolute rest and motion as empty sounds without sense, he is not only constrained also to reject the laws of motion, but to affirm that there are no laws of motion. For, if the question which has brought us to this point, What will be the condition of a solitary body detached from its connection with other bodies? is absurd, then those things also which are induced in this body by the action of others become uncertain and indeterminable, and thus everything will have to be taken as happening fortuitously and without any reason.' [*Footnote: Ib.*, p. 32.]

That the basis of all this reasoning is purely ontological is plain. And, when the thinkers of the eighteenth century became alive to the fallacies of ontological speculation, the unsoundness of Euler's "axiom," that rest and motion are substantial attributive entities independent of all relation, could hardly escape their notice. Nevertheless, they were unable to emancipate themselves wholly from Euler's ontological prepossessions. They did not at once avoid his dilemma by repudiating it as unfounded—by denying that motion and rest can not be real without being absolute—but they attempted to reconcile the absolute reality of rest and motion with their phenomenal relativity by postulating an absolutely quiescent point or center in space to which the positions of all bodies could be referred. Foremost among those who made this attempt was Kant

[*Footnote:* It is remarkable how many of the scientific discoveries, speculations and fancies of the present day are anticipated or at least foreshadowed in the writings of Kant. Some of them are enumerated by Zoellner (Natur der Kometen, p. 455 *seq*.)—among them the constitution and motion of the system of fixed stars; the nebular origin of planetary and stellar systems; the origin, constitution and rotation of Saturn's rings and the conditions of their stability; the non-coincidence of the moon's center of gravity with her center of figure; the physical constitution of the comets; the retarding effect of the tides upon the rotation of the earth; the theory of the winds, and Dove's law. Fritz Schultze has shown (Kant and Darwin, Jena, 1875) that Kant was one of the precursors of Darwin. In this connection it is curious to note a coincidence (no doubt wholly accidental) in the example resorted to both by Kant and A. R. Wallace for the purpose of illustrating 'adaptation by general law.' The case put by both is that of the channel of a river which, in the view of the teleologists, as Wallace says (Contributions to the Theory of Natural Selection, p. 276 *seq*.), 'must have been designed, it answers its purpose so effectually,' or, as Kant expresses it, must have been scooped out by God himself. ('Wenn man die physisch-theologischen Verfasser hoert, so wird man dahin gebracht, sich vorzustellen, ihre Lanfrinnen waeren alle von Gott ausgehoehlt.' Beweisgrund zu einer Demonstration des Dasein's Gottes, Kant's Werke, i, p. 232.) Even of the vagaries of modern transcendental geometry there are suggestions in Kant's essays, Von der wahren Schaetzung der lebendigen Kraefte, Werke v, p. 5, and Von dem ersten Grunde des Unterschiedes der Gegenden im Raume, *ib*., p. 293—a fact which is not likely to conduce to the edification of those who, like J. K. Becker, Tobias, Weissenborn, Krause, etc., have raised the Kantian standard in defense of Euklidean space. It is probably not without significance that in the second edition of his Critique of Pure Reason Kant omits the third paragraph of the first section of the Transcendental Aesthetics, in which he had enforced the necessity of assuming the *a priori* character of the idea of space by the argument that without this assumption the propositions of geometry would cease to be true apodictically, and that 'all that could be said of the dimensions of space would be that *thus far* no space had been found which had more than three dimensions.']

In the seventh chapter of his 'Natural History of the Heavens'—the same work in which, nearly fifty years before Laplace, he gave the first outlines of the Nebular Hypothesis—he sought to show that in the universe there is somewhere a great central body whose center of gravity is the cardinal point of reference for the motions of all bodies whatever. 'If in the immeasurable space,' he says, [*Footnote:* Naturgeschichte des Himmels, Werke, vol. vi, p. 152.] 'wherein all the suns of the milky way have been formed, a point is assumed round which, from whatever cause, the first formative action of nature had its play, then at that point a body of the largest mass and of the greatest attractions, must have been formed. This body must have become able to compel all systems which were in process of formation in the enormous surrounding sphere to gravitate toward it as their center, so as to constitute an entire system, similar to the solar and planetary system which was evolved on a small scale out of elementary matter.'

A suggestion similar to that of Kant has recently been made by Professor C. Neumann, who enforces the necessity of assuming the existence, at a definite and permanent point in space, of an absolutely rigid body, to whose center of figure or attraction all motions are to be referred, by physical considerations. The drift of his reasoning appears in the following extracts from his inaugural lecture On the Principles of the Galileo-Newtonian Theory: [*Footnote:* Ueber die Principien der Galileo-Newton'schen Theorie. Leipzig, B. G. Teubner, 1870.] The principles of the Galileo-Newtonian theories consist in two laws—the law of inertia proclaimed by Galileo, and the law of attraction added by Newton. . . . A material point, when once set in motion, free from the action of an extraneous force, and wholly left to itself, continues to move in a straight line so as to describe equal spaces in equal times. Such is Galileo's law of inertia. It is impossible that this proposition should stand in its present form as the corner-stone of a scientific edifice, as the starting-point of mathematical deductions. For it is perfectly unintelligible, inasmuch as we do not know what is meant by 'motion in a straight line,' or, rather, inasmuch as we do know that the words 'motion in a straight line' are susceptible of various interpretations. A motion, for instance, which is rectilinear as seen from the earth, would be curvilinear as seen from the sun, and would be represented by a different curve as often as we change our point of observation to Jupiter, to Saturn, or another celestial body. In short, every motion which is rectilinear with reference to one celestial body will appear curvilinear with reference to another celestial body. . . .

'The words of Galileo, according to which a material point left to itself proceeds in a straight line, appear to us, therefore, as words without meaning—as expressing a proposition which, to become intelligible, is in need of a definite background. *There must be given in the universe some special body as the basis of our comparison*, *as the object in reference to which all motions are to be estimated;* and only when such a body is given shall we be able to attach to those words a definite meaning. Now, what body is it which is to occupy this eminent position? Or, are there several such bodies? Are the motions near the earth to be referred to the terrestrial globe, perhaps, and those near the sun to the solar sphere? . . .

'Unfortunately, neither Galileo nor Newton gives us a definite answer to this question. But, if we carefully examine the theoretical structure which they erected, and which has since been continually enlarged, its foundations can no longer remain hidden. *We readily see that all actual or imaginable motions in the universe must be referred to one and the same body.* Where this body is, and what are the reasons for assigning to *it* this eminent, and, as it were, sovereign position, these are questions to which there is no answer.

'*It will be necessary, therefore, to establish the proposition, as the first principle of the Galileo-Newtonian theory, that in some unknown place of the universe there is an unknown body—a body absolutely rigid and unchangeable for all time in its figure and dimensions. I may be permitted to call this body* 'THE BODY ALPHA.' *It would then be necessary to add that the motion of a body would import, not its change of place in reference to the earth or sun, but its change of position in reference to the body Alpha.*

'From this point of view the law of Galileo is seen to have a definite meaning. This meaning presents itself as a second principle, which is, that a material point left to itself progresses in a straight line—proceeds, therefore, in a course which is rectilinear in reference to the body Alpha.'

After thus showing, or attempting to show, that the reality of motion necessitates its reference to a rigid body unchangeable in its position in space, Neumann seeks to verify this assumption by asking himself the question, what consequences would ensue, on the hypothesis of the mere relativity of motion, if all bodies but one were annihilated. 'Let us suppose,' he says, 'that among the stars there is one which consists of fluid matter, and which, like our earth, is in rotatory motion round an axis passing through its center. In consequence of this motion, by virtue of the centrifugal forces developed by it, this star will have the form of an ellipsoid. What form, now, I ask, will this star assume if suddenly all other celestial bodies are annihilated?

'These centrifugal forces depend solely upon the state of the star itself; they are wholly independent of the other celestial bodies. These forces, therefore, as well as the ellipsoidal form, will persist, irrespective of the continued existence or disappearance of the other bodies. But, if motion is defined as something relative—as a relative change of place of two points—the answer is very different. If, on this assumption, we suppose all other celestial bodies to be annihilated, nothing remains but the material points of which the star in question itself consists. But, then, these points do not change their relative positions, and are therefore at rest. It follows that the star must be at rest at the moment when the annihilation of the other bodies takes place, and therefore must assume the spherical form taken by all bodies in a state of rest. A contradiction so intolerable can be avoided only by abandoning the assumption of the relativity of motion, and conceiving motion as absolute, so that thus we are again led to the principle of the body Alpha.'

Now, what answer can be made to this reasoning of Professor Neumann?

None, if we grant the admissibility of the hypothesis of the annihilation of all bodies in space but one, and the admissibility of the further assumption that an absolutely rigid body with an absolutely fixed place in the universe is possible. But such a concession is forbidden by the universal principle of relativity. In the first place, the annihilation of all bodies but one would not only destroy the *motion* of this one remaining body and bring it to rest, as Professor Neumann sees, but would also destroy its very *existence* and bring it to naught, as he does not see. A body can not survive the system of relations in which alone it has its being; its *presence* or *position* in space is no more possible without reference to other bodies than its *change of position or presence* is possible without such reference. As has been abundantly shown, all properties of a body which constitute the elements of its distinguishable presence in space are in their nature relations and imply terms beyond the body itself.

In the second place the absolute fixity in space attributed to the body Alpha is impossible under the known conditions of reality. The fixity of a point in space involves the permanence of its distances from at least four other fixed points not in the same plane. But the fixity of these several points again depends on the constancy of their distances from other fixed points, and so on *ad infinitum*. In short, the fixity of position of any body in space is possible only on the supposition of the absolute finitude of the universe; and this leads to the theory of the essential curvature of space, and the other theories of modern transcendental geometry, which will be discussed hereafter.

There is but one issue from the perplexities of Euler, and that is through the proposition that the reality of rest and motion, far from presupposing that they are absolute, depends upon their relativity. The source of these perplexities is readily discovered. It is to be found in the old metaphysical doctrine, that the Real is not only distinct from, but the exact opposite of, the Phenomenal. Phenomenalities are the deliverances of sense; and these are said to be contradictory of each other, and therefore delusive. Now, the truth is that there is no physical reality which is not phenomenal. The only test of physical reality is sensible experience. And the assertion, that the testimony of the senses is delusive, in the sense in which this assertion is made by the metaphysicians, is groundless. The testimony of the senses is conflicting only because the momentary deliverance of each sense is fragmentary and requires control and rectification, either by other deliverances of the same sense, or by the deliverances of the other senses. When the traveler in the desert sees before him a lake which continually recedes and finally disappears, proving to be the effect of *mirage*, it is said that he is deceived by his senses, inasmuch as the supposed body of water was a mere appearance without reality. But the senses were not deceptive. The lake was as real as the image. The deception lay in the erroneous inferences of the traveler, who did not take into account all the facts, forgetting (or being ignorant of) the refraction of the rays proceeding from the real object, whereby their direction and the apparent position of the object were changed. The true distinction between the Apparent and the Real is that the former is a partial deliverance of sense which is mistaken for the whole deliverance. The deception or illusion results from the circumstance that the senses are not properly and exhaustively interrogated and that their whole story is not heard.

The coercive power of the prevailing ontological notions of Euler's time over the clear intellect of the great mathematician is most strikingly exhibited in his statement that without the assumption of absolute space and motion there could be no laws of motion, so that all the phenomena of physical action would become uncertain and indeterminable. If this argument were well founded, the same consequence would follow, *a fortiori*, from his repeated admissions in the first chapter of his book, to the effect that we have no actual knowledge of rest and motion, except that derived from bodies at rest or in motion in reference to other bodies. Euler's proposition can have no other meaning than this, that the laws of motion can not be established or verified unless we know its absolute direction and its absolute rate. But such knowledge is by his own showing unattainable. It follows, therefore, that the establishment and verification of the laws of motion are impossible. And yet no one knew better than Euler himself that all experimental ascertainment and verification of dynamical laws *like all acts of cognition*, depend upon the insulation of phenomena; that they can be effected only by disentangling the effects of certain forces from the effects of other forces (determinable *aliunde,* i. e., by their other effects) with which they are complicated—a proceeding which, in many cases, is facilitated by the circumstance that these latter effects are inappreciably small. Surely the verification of the law of inertia by the inhabitants of our planet does not depend upon their knowledge, at any moment, of the exact rate of its angular velocity of motion round the sun! And the validity of the Newtonian theory of celestial motion is not to be drawn in question because its author suggests that the center of gravity of our solar system moves in some elliptic orbit whose elements are not only unknown, but will probably never be discovered! As well might it be contended that the mathematical theorems respecting the properties of the ellipse are of doubtful validity, since no such curve is accurately described by any celestial body or can be exactly traced by a human hand!

Although in particular operations of thought we may be constrained, for the moment, to treat the Complex as simple, the Variable as constant, the Transitory as permanent, and thus in a sense to view phenomena '*sub quadam specie absoluti*,' [*Footnote:* 'De naturâ rationis est res sub quadam æternitatis specie percipere.' Spinoza, Eth., Pars. ii, Prop. xliv, Coroll. 2.] nevertheless there is no truth in the old ontological maxim that the true nature of things can be discovered only by divesting them of their relations—that to be truly known they must be known as they are in themselves, in their absolute essence. Such knowledge is impossible, all cognition being founded upon a recognition of relations; and this impossibility nowhere stands out in stronger relief than in the exposition, by Newton and Euler, of the reality of rest and motion under the conditions of their determinability.

It follows, of course, from the essential relativity of rest and motion, that the old ontological disjunction between them falls, and that in a double sense rest differs from motion, in the language of Euler, 'as one motion differs from another,' [*Footnote:* 'Neque motus a quiete aliter differt, atque alius motus ab alio.' Theoria motûs, etc., p. 8.] or, as modern mathematicians and physicists express it, that 'rest is but a special case of motion.' [Notation, "Die Ruhe ist nur ein besonderer Fall der Bewegung." Kirchhoff, Vorlesungen ueber math. Physik, p. 32.] And it follows, furthermore, that rest is not the logically or cosmologically *primum,* of material existence—that it is not the natural and original state of the universe which requires no explanation while its motion, or that of its parts, is to be accounted for. What requires, and is susceptible of, explanation is always a change from a given state of relative rest or motion of a finite material system; and the explanation always consists in the exhibition of an equivalent change in another material system. The question respecting the origin of motion in the universe as a whole, therefore, admits of no answer, because it is a question without intelligible meaning.

The same considerations which evince the relativity of motion also attest the relativity of its conceptual elements, space and time. As to space, this is at once apparent. And of time, 'the great independent variable' whose supposed constant flow is said to be the ultimate measure of all things, it is sufficient to observe that it is itself measured by the recurrence of certain relative positions of objects or points in space, and that the periods of this recurrence are variable, depending upon variable physical conditions. This is as true of the data of our modern time-keepers, the clock and chronometer, as of those of the clepsydra and hour-glass of the ancients, all of which are subject to variations of friction, temperature, changes in the intensity of gravitation, according to the latitude of the places of observation, and so on. And it is equally true of the records of the great celestial time-keepers, the sun and the stars. After we have reduced our apparent solar day to the mean solar day, and this, again, to the sidereal day, we find that the interval between any two transits of the equinoctial points is not constant, but becomes irregular in consequence of nutation, of the precession of the equinoxes, and of numerous other secular perturbations and variations due to the mutual attraction of the heavenly bodies. The constancy of the efflux of time, like that of the spatial positions which serve as the basis for our determination of the rates and amounts of physical motion, is purely conceptual.

The relativity of mass has repeatedly been adverted to in the preceding chapters. It has been shown that the measure of mass is the reciprocal of the amount of acceleration produced in a body by a given force, while force, in turn, is measured by the acceleration produced in a given mass. It is readily seen that the concept mass might be expanded, so as to assign the measure of mass, not to mechanical motion alone, but to physical action generally,

> including heat and chemical affinity. This would lead to an equivalence of masses differing with the nature of the agency selected as the basis of the comparison. Thermally equivalent masses would be the reciprocals of the specific heats of masses as now determined; and chemically equivalent masses would be the atomic weights, so called. It is important to note that the determination of masses on the basis of gravitation, in preference to their valuation on the basis of thermal, chemical or other physical action, is a mere matter of convenience, and is not in any proper sense founded on the nature of things.
>
> But, apart from this, and looking to the ordinary method of determining the mass of a body by its weight, the relativity of mass is equally manifest. The weight of a body is a function, not of its own mass alone, but also of that of the body or bodies by which it is attracted, and of the distance between them. A body whose weight, as ascertained by the spring-balance or pendulum, is a pound on the surface of the earth, would weigh but two ounces on the moon, less than one fourth of an ounce on several of the smaller planets, about six ounces on Mars, two and one half pounds on Jupiter, and more than twenty-seven pounds on the sun. And while the fall of bodies, *in vacuo*, near the surface of the earth amounts to about sixteen feet (more or less, according to the latitude) during the first second, their corresponding fall near the surface of the sun is more than four hundred and thirty-five feet.
>
> The thoughtlessness with which it is assumed by some of the most eminent physicists that matter is composed of particles which have an absolute primordial weight persisting in all positions and under all circumstances, is one of the most remarkable facts in the history of science. 'The absolute weight of atoms,' says Professor Redtenbacher, [*Footnote:* Dynamidensystem (Mannheim, Bassermann, 1857), p. 14.] 'is unknown'—his meaning being, as is evident from the context, and from the whole tenor of his discussion, that our ignorance of this absolute weight is due solely to the practical impossibility of insulating an atom, and of contriving instruments delicate enough to weigh it.
>
> There is nothing absolute or unconditioned in the world of objective reality. As there is no absolute standard of quality, so there is no absolute measure of duration, nor is there an absolute system of coördinates in space to which the positions of bodies and their changes can be referred. A physical *ens per se* and a physical constant are alike impossible, for all physical existence resolves itself into action and reaction, and action imports change."

Ernst Mach, perhaps in reaction to Carl Neumann's hypothesis of the "Body Alpha", and in agreement with Berkeley, Stallo, *et al.*, proclaimed,

> "The expression 'absolute motion of translation' Streintz correctly pronounces as devoid of meaning and consequently declares certain analytical deductions, to which he refers, superfluous. On the other hand,

with respect to *rotation,* Streintz accepts Newton's position, that absolute rotation can be distinguished from relative rotation. In this point of view, therefore, one can select every body not affected with absolute rotation as a body of reference for the expression of the law of inertia.

I cannot share this view. For me, only relative motions exist (*Erhaltung der Arbeit*, p. 48; *Science of Mechanics,* p. 229), and I can see, in this regard, no distinction between rotation and translation. When a body moves relatively to the fixed stars, centrifugal forces are produced; when it moves relatively to some different body, and not relatively to the fixed stars, no centrifugal forces are produced. I have no objection to calling the first rotation 'absolute' rotation, if it be remembered that nothing is meant by such a designation except *relative rotation with respect to the fixed stars.* Can we fix Newton's bucket of water, rotate the fixed stars, and *then* prove the absence of centrifugal forces?

The experiment is impossible, the idea is meaningless, for the two cases are not, in sense-perception, distinguishable from each other. I accordingly regard these two cases as the *same* case and Newton's distinction as an illusion (*Science of Mechanics,* page 232)."[2956]

In 1879, Hermann Lotze, who like Faraday argued for a Boscovichian dynamism of atoms as centers of force, presented a thought experiment regarding the speed of the propagation of forces in 1879,

"**206.** Connected with this question is the other one: Do forces, in order to take effect, require Time? Stated in this form, indeed, as it occasionally is, the question is ambiguous. It is a universally admitted truth that, every effect, in its final result, is formed by the successive and continuous addition of infinitesimal parts which go on accumulating from zero up to the final amount. In this sense succession, in other words, expenditure of Time, is a characteristic of every effect, and this is what distinguishes an effect from a mere consequence, which holds good simultaneously with its condition. Vain, however, would it be—as we saw in our investigation of Time—to seek to go further than this, and to discover the inscrutable process by means of which succession of events in Time comes to pass at all. The question we are considering was proposed on the assumption of the diffusion of force in Space. Supposing it were possible to instance a moment of Time in which a previously non-existent force came into Being, would all the various effects which it was calculated to produce in different places, both near and remote, be at once realised? Or, would a certain interval of Time be required, just as it is in the case of Light, which transmits itself to different objects rapidly, but not instantaneously, and must first come into contact with them before it can he reflected by them."[2957]

George-Louis Le Sage, Rudolf Mewes, S. Tolver Preston, Hendrik Antoon Lorentz, Henri Poincaré and Paul Gerber, among others, set the speed of the propagation of gravitational effects at the speed of light long before Einstein. Others opposed this view. Joseph Henry stated,

> "According to the view we have given, a portion of matter consists of an assemblage of indivisible and indestructible atoms endowed with attracting and repelling forces, and with the property of obedience to the three laws of motion [viz.: inertia, coexistence of separate motions, and equality of action and reaction]. All the other properties, and indeed all the mechanical phenomena of matter, so far as they have been analyzed, are probably referable to the action of such atoms, arranged in groups of different orders, . . . the distance in all cases between any two atoms being much greater than the diameter of the atoms or molecules. We are obliged to assume the existence of an ethereal medium formed of atoms, which are endowed with precisely the same properties as those we have assigned to common matter; and this assumption leads us to the inference that matter is diffused through all space.
>
> That something exists between us and the sun, possessing the properties of matter, may be inferred from the simple fact that time is required for the transmission of light and heat through the intervening space. . . . That the phenomena of light and heat from the sun are not the effect of the transmission of mere force (without intervening matter), such as that of attraction and repulsion, is evident from the fact that these [latter] actions require no perceptible time for their transmission to the most distant parts of the solar system. If the sun were to be at once annihilated, the planet Neptune would at the same instant begin to move in a tangent to its present orbit."[2958]

Ernst Mach saw the notion that gravity should propagate at light speed as an indication that the æther is a medium for the propagation of gravitational effects. Gerber's alleged theory of action at a distance at light speed was seen as untenable.

Ernst Brücke wrote, in 1857,

> "Let us suppose a portion of the masses which gravitate towards each other to be destroyed; then certainly not only accelerating force, but also, according to circumstances, a portion of the tension or of the *vis viva*, or of both, would be destroyed: but this only confirms us in our way of viewing the subject. The law of the indestructibility of matter has been proved as universally valid as that of the conservation of force. That the destruction of the one should involve that of the other, only shows us that both stand in intimate connexion with each other, and proves that we are right in placing the cause of the notion of gravity in the masses themselves, and not in the space between them.
>
> Thus in all that has been hitherto said, so far as my consciousness reaches, so far as I am capable of distinguishing true from false, and like from unlike, all known facts are brought into complete harmony with our laws of thought when we suppose forces, as the causes of phænomena, to

reside in the masses, the spaces between these masses being traversed by the forces. If the forces could be imagined as existing in space, it must also be conceivable that matter may be annihilated without changing the sum of forces, and this, at least by me, is not conceivable."[2959]

George Stuart Fullerton wrote in 1901,

"To the question whether the void spaces are real, we may answer: Yes, if we mean by this only that things really stand to each other in such and such relations; or in other words, that they are at such and such distances from one another. No, if we mean that the relation is to be turned into a real thing that is supposed to remain when the things between which it obtains are taken away. The real world which we build up out of our experiences is a world of things of a certain kind; it is a world of extended things separated by distances, and the things influence each other in definite ways which cannot be described if the relations of the things—their distances and directions—be left out of account. It is one thing to recognize the relations between things as real, and it is quite another to turn those relations into things of an unreal and equivocal sort. It is one thing to recognize that things are at a distance from each other, and another to turn the distance itself into the ghost of a thing.

But, it may be objected, when we speak of space we mean *more* than the actual system of relations which obtains between extended things. I answer, we undoubtedly do; we mean, not merely the actual system of relations, but the system of all theoretically possible relations as well. The actual relations of things are constantly changing, and the relations which happen to exist at any moment may be regarded as merely representative of an indefinite number of other relations which might just as well have been actual. We have seen that *real* things are never given in a single intuition, and that what may be thus given can, at best, be regarded as merely representative of an indefinite series of possible experiences which in their totality express the nature of the thing. In the same way we may say that *real* space, which is the whole system of relations of a certain kind between real things, cannot be the object of a single intuition. By real space we never mean only this particular distance given in this particular experience. We mean all the actual and theoretically possible space-relations of real things in the real world.

About time one may reason in precisely the same way. Space and time are, thus, abstractions. They are the *plan* of the real world with its actual and possible changes. But this plan is not a something of which we have a knowledge independent of our knowledge of the world. This ought, I think, to be clear to any one who has followed the reasonings of the paper on the Berkeleian Doctrine of Space. We certainly do not perceive immediately that space and time are infinitely divisible. Subdivision speedily appears to result in the simple in each case. Why, then, do we assume that they are thus divisible? No conceivable reason can be given save that, in our experience of the world, such a system of substitutions obtains—a system within which the seemingly indivisible intuitive experience takes its place as the representative of experiences that are divisible, and, magnifying its function, sinks into individual insignificance. The plan stands out; the particular experience is lost sight of so completely that many able writers are capable of wholly misconceiving its nature. The plan is, then, abstracted from our experience of the world of things; but when we have the plan we can work more or less independently of the experiences from which it has been abstracted, and we can satisfy ourselves, by verifying our results from time to time, that we are not wandering in the region of dreams, but are doing something that has a meaning within the realm of nature. But what meaning could a millionth of a millimeter or a thousandth of a second have to one who had never had the complex series of experiences which reveals real things and real events? They are not given in any experience except symbolically, and the only thing that can give significance to our symbol is the series of experiences in which a real world is revealed.

Hence, to the question whether a vacuum can be conceived to exist within the world, I answer: Undoubtedly it can. But please do not substitute for the meaning: 'exist as a vacuum,' the very different meaning: 'exist as some kind of a thing.' It is easy to slip from the one meaning into the other, and philosophers have done it again and again. Space and time are the *plan* of the world-system. They really exist in the only sense in which such things can exist, *i. e.*, they really are the plan of the system. The difficulties which seem to present themselves when men inquire whether they have real existence arise out of the fact that this truth is not clearly grasped."[2960]

Duncan M'Laren Young Sommerville wrote in 1914,

"W. K. Clifford [*Footnote: The Common Sense of the Exact Sciences* (London, 1885), chap. iv. § 19.] has gone further than this and imagined that the phenomena of electricity, etc., might be explained by periodic variations in the curvature of space. But we cannot now say that this three-dimensional universe in which we have our experience is *space* in the old sense, for space, as distinct from matter, consists of a changeless set of terms in changeless relations. There are two alternatives. We must either conceive that space is really of four dimensions and our universe is an extended sheet of matter existing in this space; the aether [*Footnote:* Cf. W. W. Rouse Ball, 'A hypothesis relating to the nature of the ether and gravity,' *Messenger of Math.*, **21** (1891).] if we like; and then, just as a plane surface is to our three-dimensional intelligence a pure abstraction, so our whole universe will become an ideal abstraction existing only in a mind that perceives space of four dimensions—an argument which has been brought to the support of Bishop Berkeley! [*Footnote:* C. H. Hinton, *Scientific Romances*, First Series, p. 31 (London, 1886). For other four-dimensional theories of physical phenomena see Hinton, *The Fourth Dimension* (London, 1904).] Or, we must resist our innate tendencies to separate out space and bodies as distinct entities, and attempt to build up a monistic theory of the physical world in terms of a single set of entities, material points, conceived as altering their relations with time. [*Footnote:* Cf. A. N. Whitehead, 'On mathematical concepts of the material world,' *Phil. Trans*., A **205** (1906)] In either case it is not space that is altering its qualities, but matter which is changing its form or relations with time."[2961]

and, quoting C. D. Broad,

"**12. The inextricable entanglement of space and matter.**

A further point—and this is the 'vicious circle' of which we spoke above—arises in connection with the astronomical attempts to determine the nature of space. These experiments are based upon the received laws of astronomy and optics, which are themselves based upon the euclidean assumption. It might well happen, then, that a discrepancy observed in the sum of the angles of a triangle could admit of an explanation by some modification of these laws, or that even the absence of any such discrepancy might still be compatible with the assumptions of non-euclidean geometry.

'All measurement involves both physical and geometrical assumptions, and the two things, space and matter, are not given separately, but analysed out of a common experience. Subject to the general condition that space is to be changeless and matter to move about in space, we can explain the same observed results in many different ways by making compensatory changes in the qualities that we assign to space and the qualities we assign to matter. Hence it seems theoretically impossible to decide by any experiment what are the qualities of one of them in distinction from the other.'"[2962]

Einstein made remarks in a letter in 1916 which are derivative of Berkeley's *De Motu*, including among others,

"If I let all things vanish from the Universe, then, according to Newton, Galileo's space of inertia lingers, but in my opinion, *nothing* remains."

"Wenn ich alle Dinge aus der Welt verschwinden lasse, so bleibt nach Newton der Galileische Trägheitsraum, nach meiner Auffassung aber *nichts* übrig."[2963]

Einstein was quoted in *The Chicago Tribune* on 4 April 1921 on page 6,

"Up to this time the conceptions of time and space have been such that if everything in the universe were taken away, if there was nothing left, there would still be left to man time and space. But under this theory even time and space would cease to exist, because they are unalterably bound up with the conceptions of matter."

Einstein again took his lead from Faraday, Clifford and Brücke. Einstein changed direction from his materialistic Boscovichian misinterpretation of Mach's theory of inertia. Einstein adopted, without any attribution, Clifford's complete reification of abstract geometry, and stated, in 1930,

> "We may summarize in symbolical language. Space, brought to light by the corporeal object, made a physical reality by NEWTON, has in the last few decades swallowed ether and time and seems about to swallow also the field and the corpuscles, so that it remains as the sole medium of reality."[2964]

and,

> "The strange conclusion to which we have come is this—that now it appears that space will have to be regarded as a primary thing and that matter is derived from it, so to speak, as a secondary result. Space is now turning around and eating up matter. We have always regarded matter as a primary thing and space as a secondary result. Space is now having its revenge, so to speak, and is eating up matter. But that is still a pious wish."[2965]

14.6 The Rubber Sheet Analogy

It is interesting to note that William James gave us the "rubber sheet analogy" as a demonstrative space-time tool, in 1890, though in a different sense from the theory of relativity.[2966] James wrote extensively on the nature of space and time, and on the concept of a block universe and free will. Albert Einstein was quoted in *The London Times*, on 13 June 1921, on page 11,

> "'My own philosophic development,' he went on, 'was from Hume to Mach and James.'"
>
> James wrote,
>
> "They are made of the same 'mind-stuff,' and form an unbroken stream. [***] We can easily add all these plane sections together to make a solid, one of whose solid dimensions will represent time, whilst a cut across this at right angles will give the thought's content at the moment when the cut is made.
>
> Let it be the thought, 'I am the same I that I was yesterday.' If at the fourth moment of time we annihilate the thinker and examine how the last pulsation

of his consciousness was made, we find that it was an awareness of the whole content with *same* most prominent, and the other parts of the thing known relatively less distinct. With each prolongation of the scheme in the time-direction, the summit of the curve of section would come further towards the end of the sentence. If we make a solid wooden frame with the sentence written on its front, and the time-scale on one of its sides, if we spread flatly a sheet of India rubber over its top, on which rectangular co-ordinates are painted, and slide a smooth ball under the rubber in the direction from 0 to 'yesterday,' the bulging of the membrane along this diagonal at successive moments will symbolize the changing of the thought's content in a way plain enough, after what has been said, to call for no more explanation. Or to express it in cerebral terms, it will show the relative intensities, at successive moments, of the several nerve-processes to which the various parts of the thought-object correspond."

14.7 Reference Frames and Covariance

In 1885, Ludwig Lange relativized Newton's kinematic absolutism, by providing it with an experimental dynamic framework and definition, which he dubbed the "inertial system".[2967] Lange then generalized his theory in 1902.[2968] After Einstein became famous, Lange sought in vain for widespread recognition of his insights and nomenclature and for his pioneering work against ontological absolutism.[2969]

Einstein often gave descriptions reminiscent of Berkeley's[2970] and Lange's writings, which work by Lange detailed the work of Mach and Budde, which Einstein repeated virtually verbatim.[2971] Before being pressured to give Mach credit, Einstein spoke as if these ideas were his own. Einstein wrote to Karl Schwarzschild and presented these ideas as if novel.[2972] Schwarzschild immediately recognized Lange's "Inertialsystem" described by Einstein, as well as Riemann's contributions.[2973]

For early uses of the term "Inertial System" in the theory of relativity, refer to the endnote.[2974] Max von Laue had previously called them "justified systems",[2975] a term which Einstein soon adopted.[2976] Ernst Gehrcke insisted that Lange's priority be recognized.[2977]

Einstein, in 1905, relied upon absolutist Newtonian kinematics and an axiomatic absolute "resting system" as opposed to "moving systems". Einstein's light postulate refers only to this "resting system" and the principle of relativity, for Einstein, refers only to systems in uniform motion relative to this singular system.[2978] Of those who pursued Einstein's papers, and ignoring the fact that it was Poincaré who introduced the concept of the inertial system to the special theory of relativity, it was Jakob Laub[2979] who first came closest to comprehending the import of Lange's "inertial system" in the theory of relativity, in 1907, with Laub's proposed nomenclature of "System I" and "System II", as opposed to the Einsteins' 1905 "resting system" and "moving systems". Laub's nomenclature was used by Hans Strasser in 1924.[2980]

Hermann Minkowski (1905-1909), building upon Herni Poincaré's prior works, eliminated the notion of a privileged frame of space from the Einsteins' theory, claiming that neither Lorentz nor Einstein made any attack on the concept of absolute space.[2981] Laub failed to fully incorporate the "inertial system" concept into the theory of relativity in at least three ways, though I believe he set the movement in motion. One, while asserting that absolute space "plays no role" in the Einsteins' theory, Laub still spoke in absolutes, and of rest, and failed to explicitly state that there is no such thing as absolute space. Two, he spoke of absolute empty space as the normal medium of the light wave. Three, had he denied the existence of absolute space, instead of merely asserting that it played no observable role (it plays no such observable role in Lorentz' system, either), he would have been compelled to refer the "Systems" dynamically to Newton's laws of inertia, which are kinematically understood when one proceeds from absolute space, to a moving system in uniform rectilinear translation of motion with respect to absolute space, but are by no means understood by simply asserting two arbitrary systems in uniform motion with respect to each other.

The Einsteins assert in their 1905 paper that a clock at the equator runs more slowly than a clock at one of the Earth's poles. Langevin's 1911 "paradox of the twins"[2982] is not a paradox in the Einsteins' 1905 paper, but rather a prediction of the effects of the absolute motion on moving bodies, for a clock at the equator necessarily has greater absolute velocity than a clock at one of the poles, due to the Earth's absolute rotation, and the assertion is therefore not a paradox, *per se*, but an express and internal contradiction of the Einsteins' theoretical requirement that absolute space evince no characteristic properties—that it, and its effects, be indiscernible, or, as the Einsteins euphemistically disguised it, the non-paradox is an "eigentümliche Konsequenz" of absolute motion, which later became an "unabweisbare Konsequenz" in Albert's 1911 paper. Fritz Müller put this question to Einstein in 1911, and Einstein did not dispute his analysis of the effect of absolute motion on time.[2983] The Einsteins' assertion that absolute velocity results in absolute time dilatation not only discredits Einstein's claim of priority over Lorentz for calling "Ortszeit" simply "Zeit", it is fatal to the 1905 paper as if a purely kinematic relativistic theory, as Herbert Dingle proved,

> "I now sum up the situation by stating again what must be done to avoid my conclusion. Either my equations (3) and (4) are contradictory or they are not. If they are, at least one must be wrong, and if Einstein's (3) is right, then a false step must exist in the deduction of (4) from the commonly agreed (1) and (2) which has no repercussions on the deduction of (3): this false step must be pinpointed. If, on the other hand, (3) and (4) are not contradictory, then it must be explained why Einstein's deductions from (3)—for example, that an equatorial clock goes slower than a polar one—are true, while the similar but opposite deductions from (4)—for example, that an equatorial clock goes faster than a polar one—are not equally true. In each case, therefore, either the necessary physical implications of (3) must be vindicated and those of (4) discredited, or the theory fails. No solution which makes the equations equivalent, whether meaningful or meaningless, has any bearing on the matter."[2984]

We have Mileva and Albert proclaiming in 1905,

> "One immediately sees, that this result is also still valid if the clock moves in an arbitrary polygonal line from *A* to *B*, and, of course, if the points *A* and *B* coincide.
>
> If one assumes that the result proved for a polygonal line is also valid for a continuously curved line, then one obtains the proposition: If at *A* there are two synchronously running clocks and one moves one of the clocks in a closed curve with a constant velocity, until it again arrives back at *A*, which lasts for *t* seconds, then the latter clock upon its arrival at *A* runs $\frac{1}{2}\,t\,(v\,/\,c\,)^2$ seconds slow in comparison with the unmoved clock. Therefore, one concludes that a balance-clock located at the equator must run more slowly by a very small amount, than a clock of exactly the same construction located at one of the Earth's poles, *ceteris paribus*."

The Einsteins expressly state that a clock which is (absolutely) resting records the accurate, absolute time of travel, and that a moving clock runs slow. They propose: the absolute time of the journey, the clock which has remained at rest, and the traveled clock. The Einsteins' statement quoted above (which was published before Minkowski published his theory of "worldlines") again proves that the "resting system" referred to in the 1905 paper is one at absolute rest. The Einsteins' notion that the motion of the equator with respect to a pole is a curved motion refers that motion to absolute space, a privileged frame, as the relative "motion" of equator and pole is one of relative rest. The notion that clocks would show a difference of time between equator and pole is one: that the absolute motion at the equator must, of necessity, be greater than the absolute motion of the pole; and further that time dilatation is an absolute effect, and is not a reciprocal relative effect of a measurement procedure. The Einsteins' paper is, therefore, a far more primitive understanding of relativistic concepts than Poincaré's prior work, and the Einsteins' principle of relativity is shown to be a fallacy, for the concept of absolute rest does indeed, in their theory, correspond to characteristic properties of the phenomena in electrodynamics.

We also know that the Einsteins believed in absolute space, because their 1905 paper is expressly based on Maxwell's æther theory, and they stated before introducing the Lorentz Transformation that light speed is axiomatically isotropic between points *A* and *B* at a distance from each other in the preferred "resting system". This is only axiomatically true if one assumes a preferred frame of absolute space and an æther at absolute rest, because the assertion depends upon source and observe speed independence of light speed which is only axiomatically true of the æther frame. The Einsteins then asserted in a *non sequitur* that the principle of relativity requires that if the speed of light is absolute and isotropic in absolute space, it must also be absolute and isotropic in "moving reference systems"—and on this fallacious basis they attempt to justify their repetition of Poincaré's clock synchronization procedure in "moving systems". The Einsteins fallacy results in a tautology, not a scientific approach to the problem. Poincaré and Lorentz were the superior theorists, in that they realized that a scientific exposition could not be a tautology, but must proceed on an axiomatic basis from fundamental principles, not empirical observations.

Henri Poincaré knew that a serious and complete Physics required a dynamic as well as kinematic exposition of the Lorentz Transformation. Hendrik Antoon Lorentz understood that the transformations were based on the scalar c^2 in "moving systems of reference" and that light speed anisotropy in "moving systems", not isotropy, is the actual basis of the special theory of relativity and of the Lorentz Transformation.[2985] The *æther* is detectable in the special theory of relativity even though its presumed *resting frame of reference* remains undetectable. In addition, the entire structure of the Lorentz Transformation is built upon the presumption of light speed anisotropy in moving frames of references, which fact is revealed by the use of the scalar c^2. The Einsteins' assertion of the absolute velocity of light in the "resting system" as a given axiomatic fact is an acknowledgment that the "resting system" is an æther at absolute rest, and this is how the Einsteins' define it in Part 1, Section 1 of their paper. If light speed were not anisotropic in moving frames of reference, the Lorentz Transformation would not work, because light speed would not then be measured to be c in a moving frame of reference by observers relatively resting in that moving frame—moving with respect to the æther. This has been adequately proven by Guillaume, Jánossy and others.[2986] Prof. Friedwardt Winterberg wrote,

"According to Einstein, two clocks, A and B, are synchronized if

$$t_B = \frac{1}{2}\left(t_A^1 + t_A^2\right) \qquad \text{(VII.13)}$$

where t_A^1 is the time a light signal is emitted from A to B, reflected at B back to A, arriving at A at the time t_A^2, and where it is <u>assumed</u> that the time t_B at which the reflection at B takes place is equal the arithmetic average of t_A^1 and t_A^2. Only by making this assumption does the velocity of light turn out always to be isotropic and equal to c. From an absolute point of view, the following is rather true: If t_R is the absolute reflection time of the light signal at clock B, one has for the out and return journeys of the light signal from A to B and back to A, if measured by an observer in an absolute system at rest in the distinguished reference system:

$$\begin{aligned} \gamma\left(t_R - t_A^1\right) &= d/c_+, \\ \gamma\left(t_A^2 - t_R\right) &= d/c_- \end{aligned} \qquad \text{(VII.14)}$$

where d is the distance between both clocks, and where c_+ and c_- are given by

$$c_+ = \sqrt{c^2 - v^2 \sin^2 \psi} - v \cos \psi$$

$$c_- = \sqrt{c^2 - v^2 \sin^2 \psi} + v \cos \psi$$

Adding the equations (VII.14) one obtains

$$c\left(t_A^2 - t_A^1\right) = 2\gamma d \sqrt{1 - \left(v^2/c^2\right) \sin^2 \psi} \qquad \text{(VII.15)}$$

If an observer at rest with the clock wants to measure the distance from A to B, he can measure the time it takes a light signal to go from A to B and back to A. If he assumes that the velocity of light is constant and isotropic in all inertial reference systems, including the one he is in, moving together with A and B with the absolute velocity v, this distance is

$$d' = (c/2)\left(t_A^2 - t_A^1\right) \qquad \text{(VII.16)}$$

and because of (VII.15)

$$d' = \gamma d \sqrt{1 - \left(v^2/c^2\right) \sin^2 \psi} \qquad \text{(VII.17)}$$

Comparing this result with,

$$l' = l\sqrt{1 - \left(v^2/c^2\right) \cos^2 \varphi} = \frac{l}{\gamma \sqrt{1 - \left(v^2/c^2\right) \sin^2 \psi}}$$

one sees that he would obtain the same distance d', if he uses a contracted rod as a measuring stick, of Einstein's constant light velocity postulate. The velocity of light between A and B by using a rod to measure the distance and the time it takes a light signal in going from A to B and back to A, of course, will turn out to be equal to c, because according to (VII.16)

$$\frac{2d'}{t_A^2 - t_A^1} = c \qquad \text{(VII.18)}$$

Rather than using a reflected light signal to measure the distance d', the observer at A may try to measure the one-way velocity of light by first synchronizing the clock B with A and then measure the time for a light signal to go from A to B. However, since this synchronization procedure also uses reflected light signals, the result is the same. For the velocity he finds

$$\frac{d}{t_B - t_A^1} = \frac{d'}{(1/2)\left(t_A^1 + t_A^2\right) - t_A^1} = \frac{2d'}{t_A^2 - t_A^1} = c \qquad \text{(VII.19)}$$

By subtracting the equations (VII.14) one finds that

$$t_R = t_B + \left(\gamma/c^2\right) v d \cos\psi \qquad \text{(VII.20)}$$

which shows that from an absolute point of view the 'true' reflection time t_R at clock B is only then equal to t_B if $v = 0$. From an absolute point of view the propagation of light is isotropic only in the distinguished reference system, but anisotropic in a reference system in absolute motion against the distinguished reference system. This anisotropy remains hidden due to the impossibility to measure the one way velocity of light. This impossibility is expressed in the Lorentz transformations themselves, containing the scalar c^2 rather than the vector $\underline{c}$, through which an anisotropic light propagation would have to be expressed."[2987]

The expected anisotropy from which the transformation evolved exhibits itself in the predictions the theory makes for an interferometer constructed and calibrated in an inertial reference system K_0 without rigid attachments, but instead assembled with rockets or automobiles at each of the four relevant surfaces, which after being adjusted are then simultaneously and uniformly accelerated with respect to K_0 then allowed to travel in inertial motion in inertial reference system K_1, but which do not suffer a Lorentz contraction due to the lack of rigid attachments. The special theory of relativity predicts a shift in the interference fringe pattern on the interferometer, which matches the exact result for which Michelson and Morley originally sought but did not find and which confirms light speed anisotropy in at least one of the two inertial reference systems employed in the experiment.

Lajos Jánossy proved this argument,

"§7. Im vorigen Abschnitt haben wir gezeigt, wie man ein materialles Bezugssystem K_1 konstruieren kann, das eine vollkommene G a l i l e i sche Transformation des Systems K_0 ist. Das System K_1 ist jedoch ein sehr unbequemes Bezugssystem. Wir finden nämlich, daß 1. das Licht sich in K_1 nicht isotrop ausbreitet, und 2. daß bewegte Uhren Phasenverschiebungen erleiden, auch wenn sie sehr langsam in K_1 bewegt werden; die Phasenverschiebung verschwindet auch im Grenzfall der verschwindenden Verschiebungsgeschwindigkeit nicht.

Wir zeigen zunächst, daß diese erwähnte, unbequeme Eigenschaft in K_1 tatsächlich auftritt.

1. Daß Licht sich in K_0 isotrop ausbreitet, kann durch den Michelson-Morley-Versuch gezeigt werden. Betrachten wir nun ein Interferometer in K_0, das aus vier unzusammenhängenden Teilen besteht (s. Abb. 2 [*Figure deleted*]): Eine halbversilberte Platte P, zwei Spiegel M_1 and M_2 und ein Fernohr T. Wenn wir das System drehen, so daß die relativen Entfernungen von M_1, M_2, P und T unverändert bleiben, dann wird auch das Streifensystem in T unverändert bleiben. Wenn wir nun die vier Teile des Systems unabhängig, aber gleichzeitig beschleunigen, dann bringen wir das Interferometer in des System K_1. Diese Beschleunigung wird aber das Streifensystem, das man in T sieht, beeinflussen. Diese Beschleunigung würde in der Tat eine Streifenverschiebung hervorrufen, die in Lichtzeit ausgedrückt folgenden Wert besitzt.

$$\Delta T = l\left(\frac{4}{c} - \frac{2}{\sqrt{c^2 - v^2}} - \frac{1}{c - v} - \frac{1}{c + v}\right) = -\frac{lv^2}{c^2} + \cdots . \quad (13)$$

Der obige wert der Verschiebung ist nämlich genau der, den seinerzeit Michelson und Morley erwartet hatten, aber nicht fanden. Der Unterschied zwischen dem hier beschriebenen Experiment und dem wirklichen Michelson-Morley-Experiment ist nämlich der, daß das wirkliche Interferometer nicht aus unabhängigen Bestandteilen „zusammengesetzt" ist, sondern ein festes System bildete. Wenn die Teile unseres gedachten Interferometers durch materielle Stäbe verbunden wären, dann würden die einzelnen Teile nach Vollzug der Beschleunigung durch die in den Stäben auftretenden, elastischen Kräfte verschoben werden. Wenn wir also den elastischen Kräften freies Spiel gewähren würden, dann würden sie das Interferometer im Vergleich zum System K_1 in einer solchen Weise verzerren, daß die Verzerrung die Phasenverschiebung (13) genau kompensieren würde.

Um dies ganz klar zu machen, betrachten wir schematisch ein Interferometer, dessen vier Bestandteile auf vier Autos montiert sind. Setzen wir nun voraus, daß diese Autos gleichzeitig in der in §6 beschriebenen Weise losfahren. (Wir setzen voraus, daß die Autos so glatt fahren, daß die Interferenzstreifen während der Fahrt bestehen bleiben.) Das Interferometer, das auf diese Weise in Bewegung gesetzt worden ist, wird sicher eine Phasenverschiebung zeigen. Wir haben in §6/1 darauf hingewiesen, daß elastische Bänder, die zwischen Autos gespannt sind, in Spannung geraten, wenn die Autos sich in Bewegung setzen, weil nämlich diese Bänder sich zusammenzuziehen versuchen, aber daran verhindert werden durch die Autos. Wenn wir jetzt die Autos sich einander soweit nähern lassen, daß die elastische Spannung aufhört, dann verschieben wir damit die Spiegel genau in der richtigen Weise, um die nach der Beschleunigung aufgetretene Phasenverschiebung rückgängig zu machen. Zusammenfassend sehen wir, daß die Lichtfortpflanzung in K_1 nicht der isotrop erfolgt. Dieses Resultat setzt natürlich voraus, daß wir mit der Methode der Konstruktion von K_1, wie sie in §6 beschreiben wurde, einverstanden sind."[2988]

In 1911, Albert Einstein (like Langevin) wrote, referring to a "purely kinematic consequence"—as opposed to a dynamic consequence,

"Were we, for example, to place a living organism in a box and make it perform the same to-and-fro motion as the clock discussed above, it would be possible to have this organism return to its original starting point after an arbitrarily long flight having undergone an arbitrarily small change, while identically constituted organisms that remained at rest at the point of origin have long since given way to new generations. The long time spent on the trip represented only an instant for the moving organism if the motion occurred with approximately the velocity of light! This is an inevitable consequence of our fundamental principles, imposed on us by experience."[2989]

Albert Einstein told Ernst Gehrcke in 1914 that accelerated movements are absolute,

"The clock B, which was moved, runs more slowly because it has sustained accelerations in contrast to the clock A. Certainly, these accelerations are unimportant for the amount of the time difference of both clocks, however, their existence causes the slow running just of the clock B, and not of the clock A. Accelerated motions are absolute in the theory of relativity."

"Die Uhr B, welche bewegt wurde, geht deshalb nach, weil sie im Gegensatz zu der Uhr A Beschleunigungen erlitten hat. Diese Beschleunigungen sind zwar für den Betrag der Zeitdifferenz beider Uhren belanglos, ihr Vorhandsein bedingt jedoch das Nachgehen gerade der Uhr B, und nicht der Uhr A. Beschleunigte Bewegungen sind in der Relativitätstheorie absolute."[2990]

Gehrcke recounted that,

"Mr. Einstein recently admitted to me orally that accelerations are absolute in Einstein's theory of relativity, up to now, however, he has not acknowledged that speeds in his theory are absolute. It is noteworthy in this context that in Newtonian Mechanics both translation-speeds and accelerations are *relative*, on the other hand rotational-speeds and -accelerations are absolute; I am of course in agreement with Mr. Einstein on this point (regarding Newtonian mechanics) and have proven that the often heard, contrary opinion, according to which all accelerations in Newtonian mechanics are absolute and 'inertial systems' are left to be defined mechanically, is erroneous. [***] Minkowski's theory of relativity places, like Einstein's, the reference system, to which all events are referred (therefore the absolutely resting system), in the subjective standpoint of an observer. Therefore, the theory can be characterized as a subjective theory of absolutism: subjective because the point of view of the *observer* is distinguished, absolute, because all events are referred to this standpoint and no other."

"Daß in der Relativitätstheorie EINSTEINs die Beschleunigungen absolute sind, hat mir Herr EINSTEIN neuerdings auch mündlich zugegeben, er hat jedoch bisher nicht anerkannt, daß die Geschwindigkeiten in seiner Theorie absolute sind. Im Anschluß hieran sei bemerkt, daß in der NEWTONschen Mechanik sowohl Translations-Geschwindigkeiten wie -Beschleunigungen *relative* sind, dagegen sind die Rotations-Geschwindigkeiten und -Beschleunigungen absolute; ich bin in diesem Punkte (hinsichtlich der NEWTONschen Mechanik) wohl in Übereinstimmung mit Herrn EINSTEIN, und habe bewiesen, daß die oft gehörte, gegenteilige Ansicht, nach der alle Beschleunigungen in der NEWTONschen Mechanik absolute seien und sich „Inertialsysteme" mechanisch definieren ließen, irrtümlich ist. [***] Die Relativitätstheorie von MINKOWSKI legt, wie die von EINSTEIN, das Bezugssystem, auf welches alles Geschehen zu beziehen ist (also das absolut ruhende System), in den subjektiven Standpunkt eines Beobachters. Daher läßt sich die Theorie als *subjektive Absoluttheorie* charakterisieren: subjektiv, weil der Standpunkt des *Beobachters* ausgezeichnet wird, absolut, weil alles Geschehen auf *diesen* Standpunkt und keinen anderen bezogen wird."[2991]

This history has been largely forgotten, with most today mistakenly believing that Einstein had understood the full significance of Lange's inertial systems in 1905, though Einstein had not. Einstein repeatedly described a preferred "resting system" and a particular state of motion relative to it, right up through 1916, in the special theory.

Gehrcke described the "theory of relativity" as subjective absolutism in 1914, and stated that in 1914 Einstein had told him that accelerations are absolute in the theory of relativity. Einstein then obstructed Gehrcke's efforts to publish that fact in *Die Naturwissenschaften*, while conceding that it was true.

Covariance was already raised, as an issue, in the Poincaré-Lorentz theory of relativity.[2992] Covariance has been a controversial subject.[2993] Kretschmann demonstrated that covariance is a matter of human convention, and not a principle of Nature. Einstein almost immediately stole some of Kretschmann's ideas.[2994] Dennis Overbye wrote in his book *Einstein in Love: A Scientific Romance*,

> "Kretschmann's paper, which appeared in the *Annalen der Physik* on December 21, 1915, apparently struck a chord with Einstein. By now, of course, the hole argument was an embarrassment, and he was eager for an answer. Five days later Albert wrote back to Ehrenfest, who had been pestering him about the hole problem, with an answer almost identical to Kretschmann's. Space-time points, he said, gain their identity not from coordinates but from what happens at them. The phrase he used was 'space-time coincidences.'[40]
>
> 'The physically real in the world of events (in contrast to that which is dependent upon the choice of a reference system) consists in *spatiotemporal coincidences* . . . and in nothing else!' he told Ehrenfest. Reality, he repeated to Besso, was nothing less than the sum of such point coincidences, where, say, the tracks of two electrons or a light ray and a photographic grain crossed.[41]
>
> In his magnum opus on the new general relativity theory early in March 1916, Albert paralleled Kretschmann almost word for word: 'All our space-time verifications invariably amount to a determination of space-time coincidences. . . . Moreover, the results of our measurings are nothing but verifications of meetings of the material points of our measuring instruments with other material points, coincidences between the hands of a clock and points on the clock dial, and observed point-events happening at the same place at the same time.'[42]"[2995]

The general theory of relativity is another absolutist theory and the general principle of relativity is an absolutist metaphysical convention, not a scientific principle.

Kamerlingh Onnes was another of Einstein's friends who fell victim to Einstein's career of plagiarism. Dirk van Delft wrote,

> "Einstein did, however, lecture on superconductivity at Leiden in November 1921. This time he was invited to stay at Kamerlingh Onnes's home. [***] In November 1922, Einstein set out his ideas on superconductivity in an article for the festschrift celebrating the 40th anniversary of Onnes's professorship.[11] Following discussions with Ehrenfest, Einstein had arrived at a model of 'chains of atomic electrons running almost in single file,' as he explained it in a postcard to his friend. In the superconducting state, he went on, these chains would be 'stable and undisturbed.' Einstein suggested testing his theory by measuring the self-induction of a non-superconducting coil placed beneath a short-circuited superconducting coil. His festschrift article does not contain this somewhat vague suggestion, but he did stick to his electron-chain conjecture. However, after Kamerlingh Onnes found superconductivity across a lead-tin interface, Einstein did have to retract his

hypothesis that the electron chains could not consist of different types of atoms. Surprisingly, Einstein's festschrift paper did not cite a contribution by Onnes to the 1921 Solvay conference.[12] In it, Onnes had also come up with the idea—in much greater detail than Einstein—of electrons moving via low 'threads' from atom to atom. But Einstein had not attended the 1921 Solvay conference in Brussels, so he may not have known about Onnes's contribution."[2996]

Onnes was probably aware that Einstein was plagiarist. Onnes stated,

"Einstein was led to his discoveries by building on Lorentz's work in Leiden."[2997]

Abraham Pais tells of Einstein's attempted appropriation of the Kaluza-Klein theory. Pais wrote,

"There is nothing unusual in Einstein's change of opinion about a theory being unnatural at one time and completely satisfactory some months later. What does puzzle me is a note added to the second paper [E20]: 'Herr Mandel points out to me that the results communicated by me are not new. The entire content is found in the paper by O. Klein.' An explicit reference is added to Klein's 1926 paper [K3]. I fail to understand why he published his two notes in the first place."[2998]

Poincaré stressed the importance of Riemannian geometry. Vladimir Varičak employed non-Euclidean geometry in the theory of relativity, before Einstein and Grossmann.[2999] Harry Bateman asserted his priority over Einstein in the general theory of relativity, in 1918,

"The appearance of Dr. Silberstein's recent article on 'General Relativity without the Equivalence Hypothesis'[3000] encourages me to restate my own views on the subject. I am perhaps entitled to do this as my work on the subject of General Relativity was published before that of Einstein and Kottler,[3001] and appears to have been overlooked by recent writers."[3002]

14.8 Conclusion

Kinertia refers many times to Einstein, Lorentz and Poincaré and states that he wrote to scientists around the world, presumably including Einstein. Kinertia's work on gravity and weight preceded Einstein's by many years.

Einstein asserted the primacy of the principle of equivalence in 1916,

"This opinion must be based upon the fact that we both do not denote the same thing as 'the principle of equivalence'; because in my opinion my theory rests exclusively upon this principle."[3003]

The entire basis of the general theory of relativity was a plagiarized idea.

Einstein's argument in the general theory of relativity is irrational—a fallacy of *Petitio Principii*. By 1916, Einstein had repeatedly acknowledged Eötvös' experimental results of the previous century.[3004] Therefore, there can be no disputing that Einstein argued an empirical observation, an *a posteriori* problem, as if an *a priori* first principle in order to "deduce" the principle of equivalency" as a conclusion from itself. This results in a fallacy of *Petitio Principii*, in that Einstein assumes the fact in order to prove the same fact, just as Mileva and Albert had assume light speed invariance and the principle of relativity as "postulates" in order to "deduce" light speed invariance and the principle of relativity as conclusions.

Hans Reichenbach stated,

> "The principle of the equality of inertial and gravitational mass, which incidently is also the reason for the equality of the velocities of falling bodies [***] has been confirmed to a high degree by experiments. It is mentioned explicitly by Einstein as an empirical principle constituting the basis of his principle of equivalence."[3005]

Emil Wiechert stated on 26 February 1916, that the inertial-gravitational mass equivalence is an *a posteriori* problem, not an *a priori* first principle.[3006] Hermann Weyl explained,

> "Eötvös has comparatively recently [in 1890] tested the accuracy of this law by actual experiments of the greatest refinement (*vide* note 3). The centrifugal force imparted to a body at the earth's surface by the earth's rotation is proportional to its inertial mass but its weight is proportional to its gravitational mass. The resultant of these two, the *apparent* weight, would have different directions for different bodies if gravitational and inertial mass were not proportional throughout. The absence of this difference of direction was demonstrated by Eötvös by means of the exceedingly sensitive instrument known as the torsion-balance: it enables the inertial mass of a body to be measured to the same degree of accuracy as that to which its weight may be determined by the most sensitive balance."[3007]

Einstein, himself, stated in 1913,

> "[T]he equality (proportionality) of the gravitational and inertial mass has been proved with great accuracy in an investigation of great importance to us by Eötvös [***] *Eötvös's exact experiment concerning the equality of inertial and gravitational mass supports the view that such a criterion does not exist*. We see that in this regard Eötvös's experiment plays a role similar to that of the Michelson experiment with respect to the question of whether *uniform* motion can be detected physically."[3008]

Einstein stated in *The New York Times* on 3 April 1921 on pages 1 and 13, "I first became interested in it through the question of the distribution and expansion of light in space; that is, for the first grade or step. The fact that an iron ball and a wooden ball fall to the ground at the same speed was perhaps the reason which prompted me to take the second step."

On 13 June 1921, Einstein stated,

"The theory of general relativity owes its origin primarily to the experimental fact of the numerical equality of inertial and gravitational mass of a body, a fundamental fact for which classical mechanics has given no interpretation."[3009]

Max Born stated on 16 July 1955,

"[The general theory of relativity] began with a paper published as early as December, 1907, which contains the principle of equivalence, the only empirical pillar on which the whole imposing structure of general relativity was built."[3010]

Empirical observations are not *a priori* first principles, but are instead *a posteriori* problems which much be deduced from first principles. The principle of equivalence was a very old idea.

Samuel Clarke wrote, in the early 1700's,

"IF he only affirms bare *Matter* to be Necessary: Then, besides the extreme Folly of attributing *Motion* and the *Form* of the World to *Chance*; (which senseless Opinion I think All Atheists have now given up; and therefore I shall not think my self obliged to take any Notice of it in the Sequel of this Discourse:) it may be demonstrated by many Arguments drawn from the Nature and Affections of the Thing itself, that *Matter* is not *a necessary Being*. For Instance, Thus. *Tangibility* or *Resistance*, (which is what Mathematicians very properly call *Vis inertiæ*,) is *essential* to Matter. Otherwise the word, *Matter*, will have *no determinate* Signification. *Tangibility* therefore, or *Resistance*, belonging to *All* Matter; it follows evidently, that if *All Space* were filled with *Matter*, the *Resistance* of All *Fluids* (for the Resistance of the *Parts* of *Hard Bodies* arises from Another Cause) would necessarily be *Equal*. For greater or less degrees of *Fineness* or *Subtility*, can in this case make no difference: Because the *smaller* or *finer* the parts of the Fluid are, wherewith any particular Space is filled, the *greater* in proportion is the *Number* of the parts; and consequently the *Resistance* still always Equal. But Experience shows on the contrary, that the *Resistance* of All *Fluids* is *not* equal: There being large Spaces, in which no sensible Resistance at all is made to the swiftest and most lasting Motion of the solidest Bodies. Therefore *All Space* is *not* filled with *Matter*; but, of necessary Consequence, there must be a *Vacuum*.

OR Thus. It appears from Experiments of *falling* Bodies, and from Experiments of *Pendulums*, which (being of *equal Lengths* and *unequal Gravities*) vibrate in *equal Times*; that *All Bodies* whatsoever, in Spaces void of sensible Resistance, fall from the same Height with *equal Velocities*. Now 'tis evident, that whatever *Force* causes *unequal Bodies* to move with *equal Velocities*, must be proportional to the *Quantities* of the *Bodies moved*. The Power of *Gravity* therefore in *All Bodies*, is (at equal Distances suppose from the Center of the Earth) proportional to the *Quantity of Matter* contained in each Body. For if in a Pendulum there were any *Matter* that did not *gravitate* proportionally to its *Quantity*, the *Vis Inertiæ* of that Matter would retard the Motion of the rest, so as soon to be discovered in Pendulums of equal Lengths and unequal Gravities in Spaces void of sensible Resistance. *Gravity* therefore is in all Bodies [*Footnote:* Neutoni Princip. Philosoph. Edit. 1*ma*, *p.* 304. Edit. 2*da*, *p.* 272. Edit. 3*tia p.* 294.] *proportional* to the *Quantity* of their *Matter*. And consequently, all Bodies not being equally heavy, it follows again necessarily, that [*Footnote:* Neutoni Princip. Philosoph. Edit. 1*ma*, *p.* 411. Edit. 2*da*, *p.* 368.] there must be a *Vacuum*."[3011]

Isaac Newton wrote in Book II of his *Principia*,

"SECTION VI
Of the motion and resistance of funependulous bodies.

PROPOSITION XXIV. THEOREM XIX.

The quantities of matter in funependulous bodies, whose centres of oscillation are equally distant from the centre of suspension, are in a ratio compounded of the ratio of the weights and the duplicate ratio of the times of the oscillations in vacuo.

For the velocity, which a given force can generate in a given matter in a given time, is as the force and the time directly, and the matter inversely. The greater the force or the time is, or the less the matter, the greater the velocity generated. This is manifest from the second law of motion. Now if pendulums are of the same length, the motive forces in places equally distant from the perpendicular are as the weights: and therefore if two bodies by oscillating describe equal arcs, and those arcs are divided into equal parts; since the times in which the bodies describe each of the correspondent parts of the arcs are as the times of the whole oscillations, the velocities in the correspondent parts of the oscillations will be to each other, as the motive forces and the whole times of the oscillations directly, and the quantities of matter reciprocally: and therefore the quantities of matter are as the forces and the times of the oscillations directly and the velocities reciprocally. But the velocities reciprocally are as the times, and therefore the times directly and the velocities reciprocally are as the squares of the times; and therefore the quantities of matter are as the motive forces and the squares of the times, that is, as the weights and the squares of the times. *Q.E.D.*

COR. I. Therefore if the times are equal, the quantities of matter in each of the bodies are as the weights.

COR. 2. If the weights are equal, the quantities of matter will be as the squares of the times.

COR. 3. If the quantities of matter are equal, the weights will be reciprocally as the squares of the times.

COR. 4. Whence since the squares of the times, *cæteris paribus*, are as the lengths of the pendulums; therefore if both the times and the quantities of matter are equal, the weights will be as the lengths of the pendulums.

COR. 5. And universally, the quantity of matter in the pendulous body is as the weight and the square of the time directly, and the length of the pendulum inversely.

COR. 6. But in a non-resisting medium, the quantity of matter in the pendulous body is as the comparative weight and the square of the time directly, and the length of the pendulum inversely. For the comparative weight is the motive force of the body in any heavy medium, as was shewn above; and therefore does the same thing in such a non-resisting medium, as the absolute weight does in a vacuum.

COR. 7. And hence appears a method both of comparing bodies one among another, as to the quantity of matter in each; and of comparing the weights of the same body in different places, to know the variation of its gravity. And by experiments made with the greatest accuracy, I have always found the quantity of matter in bodies to be proportional to their weight."[3012]

In Book III of the *Principia*, Newton wrote,

"PROPOSITION VI. THEOREM VI.

That all bodies gravitate towards every Planet; and that the Weights of bodies towards any the same *Planet, at equal distances from the centre of the Planet, are proportional to the quantities of matter which they severally contain.*

It has been, now of a long time, observed by others, that all sorts of heavy bodies, (allowance being made for the inequality of retardation, which they suffer from a small power of resistance in the air) descend to the Earth *from equal heights* in equal times: and that equality of times we may distinguish to a great accuracy, by the help of pendulums. I tried the thing in gold, silver, lead, glass, sand, common salt, wood, water, and wheat. I provided two wooden boxes, round and equal. I filled the one with wood, and suspended an equal weight of gold (as exactly as I could) in the centre of oscillation of the other. The boxes hanging by equal threads of 11 feet, made a couple of pendulums perfectly equal in weight and figure, and equally receiving the resistance of the air. And placing the one by the other, I observed them to play together forward and backward, for a long time, with equal vibrations. And therefore the quantity of matter in the gold (by cor. 1 and 6. prop. 24. book 2.) was to the quantity of matter in the wood, as the action of the motive force (or *vis motrix*) upon all the gold, to the action of the same upon all the wood; that is, as the weight of the one to the weight of the other. And the like happened in the other bodies. By these experiments, in bodies of the same weight, I could manifestly have discovered a difference of matter less than the thousandth part of the whole, had any such been. But, without all doubt, the nature of gravity towards the Planets, is the same as towards the Earth. For, should we imagine our terrestrial bodies removed to the orb of the Moon, and there, together with the Moon, deprived of all motion, to be let go, so as to fall together towards the Earth: it is certain, from what we have demonstrated before, that, in equal times, they would describe equal spaces with the Moon, and of consequence are to the Moon, in quantity of matter, as their weights to its weight. Moreover, since the satellites of Jupiter perform their revolutions in times which observe the sesquiplicate proportion of their distances from Jupiter's centre, their accelerative gravities towards Jupiter will be reciprocally as the squares of their distances from Jupiter's centre; that is, equal, at equal distances. And, therefore, these satellites, if supposed to fall *towards Jupiter* from equal heights, would describe equal spaces in equal times, in like manner as heavy bodies do on our Earth. And by the same argument, if the circumsolar Planets were supposed to be let fall at equal distances from the Sun, they would, in their descent towards the Sun, describe equal spaces in equal times. But forces, which equally accelerate unequal bodies, must be as those bodies; that is to say, the weights of the Planets *towards the Sun* must be as their quantities of matter. Further, that the weights of Jupiter and of his satellites towards the Sun are proportional to the several quantities of their matter, appears from the exceedingly regular motions of the satellites (by cor. 3. prop. 65, Book 1.) For if some of those bodies were more strongly attracted to the Sun in proportion to their quantity of matter, than others; the motions of the satellites would be disturbed by that inequality of attraction (by cor. 2. prop. 65. Book 1.) If, at equal distances from the Sun, any satellite in proportion to the quantity of its matter, did gravitate towards the Sun, with a force greater than Jupiter in proportion to his, according to any given proportion, suppose of d to e; then the distance between the centres of the Sun and of the satellite's orbit would be always greater than the distance between the centres of the Sun and of Jupiter, nearly in the subduplicate of that proportion; as by some computations I have found. And if the satellite did gravitate towards the Sun with a force, lesser in the proportion of *e* to *d*, the distance of the centre of the satellite's orb from the Sun, would be less than the distance of the centre of Jupiter from the Sun, in the subduplicate of the same proportion. Therefore if, at equal distances from the Sun, the accelerative gravity of any satellite towards the Sun were greater or less than the accelerative gravity of Jupiter towards the Sun, but by one $\frac{1}{1000}$ part of the whole gravity; the distance of the centre of the satellite's orbit from the Sun would be greater or less than the distance of Jupiter from the Sun, by one $\frac{1}{2000}$ part of the whole distance; that is, by a fifth part of the distance of the utmost satellite from the centre of Jupiter; an excentricity of the orbit, which would be very sensible. But the orbits of the satellites are concentric to Jupiter, and therefore the accelerative gravities of Jupiter, and of all its satellites towards the Sun, are equal among themselves. And by the same argument, the weights of Saturn and of his satellites towards the Sun, at equal distances from the Sun, are as their several quantities of matter: and the weights of the Moon and of the Earth towards the Sun, are either none, or accurately proportional to the masses of matter which they contain. But some they are by cor. 1. and 3. prop. 5.

But further, the weights of all the parts of every Planet towards any other Planet, are one to another as the matter in the several parts. For if some parts did gravitate more, others less, than for the quantity of their matter; then the whole Planet, according to the sort of parts with which it most abounds, would gravitate more or less, than in proportion to the quantity of matter in the whole. Nor is it of any moment, whether these parts are external or internal. For, if, for example, we should imagine the terrestrial bodies with us to be raised up to the orb of the Moon, to be there compared with its body: If the weights of such bodies were to the weights of the external parts of the Moon, as the quantities of matter in the one and in the other respectively; but to the weights of the internal parts, in a greater or less proportion, then likewise the weights of those bodies would be to the weight of the whole Moon, in a greater or less proportion; against what we have shewed above.

COR. 1. Hence the weights of bodies do not depend upon their forms and textures. For if the weights could be altered with the forms, they would be greater or less, according to the variety of forms, in equal matter; altogether against experience.

COR. 2. Universally, all bodies about the Earth gravitate towards the Earth; and the weights of all, at equal distances from the Earth's centre, are as the quantities of matter which they severally contain. This is the quality of all bodies within the reach of our experiments; and therefore, (by rule 3.) to be affirmed of all bodies whatsoever. If the *æther*, or any other body, were either altogether void of gravity, or were to gravitate less in proportion to its quantity of matter; then, because (according to *Aristotle*, *Des Cartes*, and others) there is no difference betwixt that and other bodies, but in *mere* form of matter, by a successive change from form to form, it might be changed at last into a body of the same condition with those which gravitate most in proportion to their quantity of matter; and, on the other hand, the heaviest bodies, acquiring the first form of that body, might by degrees, quite lose their gravity. And therefore the weights would depend upon the forms of bodies, and with those forms might be changed, contrary to what was proved in the preceding corollary.

COR. 3. All spaces are not equally Full; for if all spaces were equally full, then the specific gravity of the fluid which fills the region of the air, on account of the extreme density of the matter, would fall nothing short of the specific gravity of quick-silver, or gold, or any other the most dense body; and therefore, neither gold, nor any other body, could descend in air. For bodies do not descend in fluids, unless they are specifically heavier than the fluids. And if the quantity of matter in a given space, can, by any rarefaction, be diminished, what should hinder a diminution to infinity?

COR. 4. If all the solid particles of all bodies are of the same density, nor can be rarefied without pores a void space or vacuum must be granted. By bodies of the same density, I mean those whose *vires inertiæ* are in the proportion of their bulks.

COR. 5. The power of gravity is of a different nature from the power of magnetism. For the magnetic attraction is not as the matter attracted. Some bodies are attracted more by the magnet, others less; most bodies not at all. The power of magnetism, in one and the same body, may be and increased and diminished; and is sometimes far stronger, for the quantity of matter, than the power of gravity; and in receding from the magnet, decreases not in the duplicate, but almost in the triplicate proportion of the distance, as nearly as I could judge from some rude observations."[3013]

In 1921, J. E. Turner said of the happiest thought in Einstein's life,

"The famous Principle of Equivalence is exactly what it professes to be and nothing more—a principle of equivalence, but not therefore of explanation. That changes in a gravitational field may be equally well expressed in terms of acceleration neither explains gravitation nor explains it away[.]"[3014]

G. Burniston Brown believed that he had refuted the principle of equivalence, *see:* "Gravitational and Inertial Mass", *American Journal of Physics*, Volume 28, (1960), pp. 475-483; and "What is Wrong with Relativity?", *Bulletin of the Institute of Physics and the Physical Society*, Volume 12, (March, 1967), pp.71-77.

Lucretius[3015] argued that motion requires an empty space in which things can move. Galileo found no resistence to the motion of "material bodies" in "empty space" and concluded, in a *non sequitur*, that there is no æthereal medium. As Kinertia noted, Galileo, who was so courageous in most of his researches, perhaps is to blame, even more than Bacon, Newton, Hume, Mach or Einstein, for the pernicious attitude prevalent today that we need not seek the physical cause of gravitation, because we can just pretend that circularly defined geometrical laws of its workings constitute an exposition on the effect. In his dialogues, at 202, Galileo states,

> "SALV. The present does not seem to be the proper time to investigate the cause of the acceleration of natural motion concerning which various opinions have been expressed by various philosophers, some explaining it by attraction to the center, others to repulsion between the very small parts of the body, while still others attribute it to a certain stress in the surrounding medium which closes in behind the falling body and drives it from one of its positions to another. Now, all these fantasies, and others too, ought to be examined; but it is not really worth while. At present it is the purpose of our Author merely to investigate and to demonstrate some of the properties of accelerated motion (whatever the cause of this acceleration may be)—meaning thereby a motion, such that the momentum of its velocity [*i momenti della sua velocita*] goes on increasing after departure from rest, in simple proportionality to the time, which is the same as saying that in equal time-intervals the body receives equal increments of velocity; and if we find the properties [of accelerated motion] which will be demonstrated later are realized in freely falling and accelerated bodies, we may conclude that the assumed definition includes such a motion of falling bodies and that their speed [*accelerazione*] goes on increasing as the time and the duration of the motion."[3016]

In 1908, Sir Arthur Schuster spoke out against the emerging logical positivism which prevailed during the period of the development of the theory of relativity, and the negative impact of its intellectual cowardice and ontological solipsism on science. Note that Schuster correctly identifies the mathematics employed in the theory of relativity as metaphysical ontology, not science. Schuster stated,

> "I have during these lectures contrasted on several occasions the former tendency to base our technical explanations of natural phenomena on definite models which we can visualise and even construct, with the modern spirit which is satisfied with a mathematical formula, and symbols which frequently have no strictly definable meaning. I ought to explain the distinction between the two points of view which represent two attitudes of mind, and I can do so most shortly by referring to the history of the electro-dynamic theory of light, the main landmarks of which I have already pointed out in the second lecture. The undulatory theory—as it left the hands of Thomas Young, Fresnel and Stokes—was based on the idea that the æther possessed the properties of an elastic solid. Maxwell's medium being quite different in its behaviour, its author at first considered it to be necessary to justify the possibility of its existence, by showing how, by means of fly wheels and a peculiar cellular construction, we might produce a composite body having the required properties. Although later Maxwell laid no further stress on the ultimate construction of the medium, his ideas remained definite

and to him the displacements which constituted the motion of light possessed a concrete reality. In estimating the importance of the support which Maxwell's views have received from experiment, we must distinguish between the fundamental assumptions on which Maxwell based his investigations and the mathematical formulæ which were the outcome of these investigations. It is clearly the mathematical formulæ only which are confirmed and the same formulæ might have been derived from quite different premises. It has always been necessary, as a second step of great discovery, to clear away the immaterial portions which are almost invariable accessories of the first pioneer work, and Heinrich Hertz, who besides being an experimental investigator was a philosopher of great perspicacity, performed this part of the work thoroughly. The mathematical formula instead of being the result embodying the concrete ideas, now became the only thing which really mattered. To use an acute and celebrated expression of Gustav Kirchhoff, it is the object of science to *describe* natural phenomena, not to *explain* them. When we have expressed by an equation the correct relationship between different natural phenomena we have gone as far as we safely can, and if we go beyond we are entering on purely speculative ground. I have nothing to say against this as a philosophic doctrine, and I shall adopt it myself when lying on my death-bed, if I have then sufficient strength to philosophise on the limitations of our intellect. But while I accept the point of view as a correct death-bed doctrine, I believe it to be fatal to a healthy development of science. Granting the impossibility of penetrating beyond the most superficial layers of observed phenomena, I would put the distinction between the two attitudes of mind in this way: One glorifies our ignorance, while the other accepts it as a regrettable necessity. The practical impediment to the progress of physics, of what may reluctantly be admitted as correct metaphysics, is both real and substantial and might be illustrated almost from any recent volume of scientific periodicals. Everyone who has ever tried to add his mite to advancing knowledge must know that vagueness of ideas is his greatest stumbling-block. But this vagueness which used to be recognised as our great enemy is now being enshrined as an idol to be worshipped. We may never know what constitutes atoms or what is the real structure of the æther, why trouble therefore, it is said, to find out more about them. Is it not safer, on the contrary, to confine ourselves to a general talk on entropy, luminiferous vectors and undefined symbols expressing vaguely certain physical relationships? What really lies at the bottom of the great fascination which these new doctrines exert on the present generation is sheer cowardice: the fear of having its errors brought home to it. As one who believes that metaphysics is a study apart from physics, not to be mixed up with it, and who considers that the main object of the physicist is to add to our knowledge, without troubling himself much as to how that knowledge may ultimately be interpreted, I must warn you against the temptation of sheltering yourself behind an illusive rampart of safety. We all prefer being right to being wrong, but it is better to be wrong than to be neither right nor wrong."[3017]

Einstein wrote to Max Born on 7 September 1944,

"[. . .]I [believe] in complete law and order in a world which objectively exists, and which I, in a wildly speculative way, am trying to capture. I firmly *believe*, but I hope that someone will discover a more realistic way, or rather a more tangible basis than it has been my lot to find."[3018]

Einstein wrote to Solovine, in 1949,

"You imagine that I look back on my life's work with calm satisfaction. But from nearby it looks quite different. There is not a single concept of which I am convinced that it will stand firm, and I feel uncertain whether I am in general on the right track."[3019]

Einstein confessed shortly before his death,

"I consider it quite possible that physics cannot be based on the field concept, i. e., on continuous structures. In that case, *nothing* remains of my entire castle in the air, gravitation theory included, [and of] the rest of modern physics."[3020]

Einstein had told the general public that only twelve persons in the world were capable of understanding the theory of relativity.[3021] After that proclamation, any person who dared contest Einstein's priority was susceptible to being labeled as outside the 12 and incapable of understanding the theory. This *ad hominem* retort to challenges to the theory continues today, when pseudorelativists avoid addressing the substance of arguments against the theory and avoid addressing the facts, but instead attempt an *ad hominem* argument against those who question their beliefs, in an effort to discredit the critic, instead of addressing his or her complaints. There are many fatal flaws in the theory of relativity. When pressed for a substantial response, the response is too often, "What you say is true, but so what?"

When it was realized that Einstein repeated what others had written far earlier, some regarded it as an amazing coincidence that someone had already written what Einstein and others would later publish. For instance,

"[Boscovich's] theory also suggests curious—almost uncanny—intimations of general relativity and quantum mechanics." [3022]

The lack of footnotes in Einstein's writings was not seen as an attempt at plagiarism, but as evidence that Einstein conceived the whole soup from scratch, even though the factual record proves that the principle of relativity via the "Lorentz Transformation" was a traditional, well-known recipe. The absurdity of assuming that a lack of references indicates the absence of a knowledge of an other's works degenerates into mysticism, and we are asked to accept that Einstein did not read what was famously in print in his pet field, but was inspired,

> "if not [by] God, [then by] some otherworldly source".[3023]

Is it not clear that Einstein's silly and childish "Eureka!" stories of divine, or "otherworldly" inspiration, are fabrications meant to establish a record of priority, where no record in fact exists? For the first originators (a redundancy compelled by the subject matter) of relativity theory, the development was slow, progressive and well documented. It was an evolution, not a holy revelation.

Of course, the indoctrinated habit of scientists is to research the scientific literature before developing a theory. Why wouldn't Einstein have done so? The history of science was, after all, Einstein's passion.

Could Einstein have researched the literature on the electrodynamics of moving bodies, the relative motion of bodies and the failure to detect the motion of the Earth relative to the æther and missed the relevant works of Michelson, Larmor, Cohn, Langevin, Poincaré and Lorentz? Did God really tap Einstein on the shoulder and whisper these men's thoughts to Einstein, but didn't let Einstein in on the poorly kept *secret* that these men had already published "God's thoughts"?

Einstein is known to have extensively read Poincaré's work,[3024] and dedicated himself to reading everything Lorentz wrote,[3025] but denied knowledge of the so-called "Lorentz Transformation". Is it plausible to believe that Einstein, a supposed genius and master scientist, was completely unaware of Poincaré's, Lorentz' and Larmor's works containing the so-called "Lorentz Transformation", and the principle of relativity, which were the talk of the physics community,[3026] and the then current literature on the subject of Poincaré's "principle of relativity", and that it is coincidental that Einstein repeated much of what they wrote virtually verbatim? Is it a coincidence that Einstein repeated the same formulæ, in the same context, based on the same explanations, and experiments? Is it a coincidence that the relativity well largely ran dry after Poincaré's untimely death?

Why did Albert's supposed genius appear only after his marriage to Mileva, and why did he not accomplish major breakthroughs, on the level of the special and general theories of relativity, after he divorced her?

David Hilbert, on whom Einstein went calling for help, published the generally covariant field equations of gravitation of the general theory of relativity, before Einstein.[3027] Why, after many years of failure, did Einstein suddenly realize, within a few days after David Hilbert's work was public, the equations which Hilbert published before him, and then submit his, Einstein's, identical formulations, inductively analyzing what Hilbert had already deduced?

Should we believe that Einstein came up with the same equations independently of Hilbert, after Einstein's long and tortuous, fruitless years of struggling in vain, after asking Hilbert for help, within days of Hilbert's public release? Who was the better mathematician of the two? Who presented the theory first? Who had the better understanding of the principle of least action?[3028] Who went calling on whom for help, after years of failure? And why is it that both Hilbert and Einstein publicly acknowledged that Hilbert had the equations first?

Which one of the two had evinced a pattern of repeating the work of others, supposedly independently, later, again and again and again? What was Poincaré's contribution to the general theory of relativity, was it not in large part his conception?[3029] And what of the non-Euclidean geometry of al-Khayyāmī (Omar Khayyam),[3030] al-Tūsī (Naṣīr al-Dīn),[3031] Saccheri,[3032] Gauss,[3033] Bolyai,[3034] Lobatschewsky,[3035] Riemann,[3036] Becker,[3037] Beltrami,[3038] Betti,[3039] Flye-Ste. Marie,[3040] Genocchi,[3041] Helmholtz,[3042] Lie,[3043] Lipschitz,[3044] Schlaefli,[3045] etc.? Albert Einstein wrote to Felix Klein, on 26 March 1917, and confessed that,

> "As I have never done non-Euclidean geometry, the more obvious elliptic geometry had escaped me when I was writing my last paper."[3046]

And what of the contributions toward the general theory of relativity of Abraham,[3047] Anderssohn,[3048] Anding,[3049] Avenarius,[3050] Backlund,[3051] Robert Stawell Ball,[3052] W. W. Rouse Ball,[3053] Baltzer,[3054] Bateman,[3055] Battaglini,[3056] Baumann,[3057] Bauschinger,[3058] Beez,[3059] Behacker,[3060] Bentham,[3061] Berkeley,[3062] Bertrand,[3063] Bessel,[3064] Boisbaudran,[3065] Boisson,[3066] Du Bois-Reymond,[3067] Bolliger,[3068] Le Bon,[3069] Boscovich,[3070] Bottlinger,[3071] Boucheporn,[3072] Bresch,[3073] Brill,[3074] Brillouin,[3075] Brown,[3076] Brücke,[3077] Brückner,[3078] Bruns,[3079] Bucherer,[3080] Buchheim,[3081] Budde,[3082] Burton,[3083] Caldonazzo,[3084] Camille,[3085] Cantor,[3086] Cayley,[3087] Challis,[3088] Chapin,[3089] Charlier,[3090] Chase,[3091] Christoffel,[3092] Clausius,[3093] Clifford,[3094] Cohn,[3095] Cox,[3096] Couturat and Delboeuf,[3097] Croll,[3098] Crookes,[3099] Conway,[3100] Cranz,[3101] Cunningham,[3102] De Donder,[3103] Droste,[3104] Drude,[3105] Duhem,[3106] Dühring,[3107] Ehrenfest,[3108] Engelmeyer,[3109] Eötvös,[3110] Epstein,[3111] Erdmann,[3112] Escherich,[3113] Evershed,[3114] Faraday,[3115] Fechner,[3116] Fessenden,[3117] Fiedler,[3118] FitzGerald,[3119] Fokker,[Co-authored with Einstein paper in early 1914] Föppl,[3120] Frahm,[3121] de Francesco[3122] Frank,[3123] Frankland,[3124] Frege,[3125] Freundlich,[3126] Fricke,[3127] Benedict and Immanuel Friedlaender,[3128] Fritsch,[3129] Funcke,[3130] Gans,[3131] Gehrcke,[3132] Geissler,[3133] Gerber,[3134] Glennie,[3135] Glydén,[3136] Grassmann,[3137] Green,[3138] Grossmann,[3139] Günther,[3140] Guthrie,[3141] Guyot,[3142] Gyllenberg,[3143] Haeckel,[3144] Hall,[3145] Halphen,[3146] Härdtl,[3147] Hargreaves,[3148] Harkness,[3149] Harzer,[3150] Hasenöhrl,[3151] Hayford and Bowie,[3152] Heath,[3153] Heaviside,[3154] Hecker,[3155] Helmert,[3156] Hepperger,[3157] Herapath,[3158] Herbart,[3159] Herglotz,[3160] Hertz,[3161] Hoffmann,[3162] Höfler,[3163] Hofmann,[3164] Holzmüller,[3165] Humboldt,[3166] Hume,[3167] Hundhausen,[3168] Huntington,[3169] Hupka,[3170] Ignatowsky,[3171] Isenkrahe,[3172] Ishiwara,[3173] Jacobi,[3174] James,[3175] Jaumann,[3176] Jewell,[3177] Johannesson,[3178] Julius,[3179] Kant,[3180] Killing,[3181] "Kinertia" (Pseudonym for Robert Stevenson),[3182] Kirchhoff,[3183] Klein,[3184] Kleinpeter,[3185] Kober,[3186] König,[3187] Kottler[3188] (father of the "Relativitätstheorie" in 1903), Kretschmann,[3189] Kronecker,[3190] Lamé,[3191] Lamla,[3192] F. Lange,[3193] L. Lange,[3194] Laplace,[3195] Larmor,[3196] Lehmann,[3197] Lehmann-Filhés,[3198] Lense,[3199] Leray,[3200] Le Roy,[3201] Levi-Civita,[3202] Lévy,[3203] Lewes,[3204] Liebmann,[3205] Liénard,[3206] Liman,[3207] Lindemann,[3208] Locke,[3209] Lorentz,[3210] Lotze,[3211] Love,[3212] MacGregor,[3213] Mach,[3214] Maupertuis, Mayer,[3215] Mehler,[3216] Mehmke,[3217] Mewes,[3218] Mie,[3219] Minkowski,[3220] Mossotti,[3221] Most,[3222] Mosengeil,[3223] Müller,[3224] Nagy,[3225] Neumann,[3226] Newcomb,[3227] E. Noble,[3228] E. Noether,[3229] F. Noether,[3230] M. Noether,[3231] Nordström,[3232] Oppenheim,[3233] Oppolzer,[3234] D'Ovidio,[3235] Pavanini,[3236] Pasley,[3237] Pearson,[3238] Petzoldt,[3239] Planck,[3240] Poe,[3241] Poynting,[3242] Preston,[3243] Pringsheim,[3244] Reich,[3245] Reissner,[3246] Ricci, Ritz,[3247] Rosenberger,[3248] Rysának,[3249] Le Sage,[3250] Saigey,[3251] St. John,[3252] Saleta,[3253] Salmon,[3254] Scheibner,[3255] Schering,[3256] Schlegel,[3257] Schott,[3258] Schramm,[3259] Schulhof,[3260] Schuster,[3261] Schütz,[3262] Schwarzschild,[3263] de Schweydar,[3264] Secchi,[3265] See,[3266] Seegers,[3267] Seeliger,[3268] Seguin,[3269] Servus,[3270] Silberstein,[3271] de Sitter,[3272] Soldner,[3273] Sommerfeld,[3274] Somoff,[3275] Souchon,[3276] Spiller,[3277] Spottiswoode,[3278] Stahl,[3279] Stallo,[3280] Stolz,[3281] Streintz,[3282] Stroh,[3283] Thirring,[3284] de Tilly,[3285] Tisserand,[3286] Tunzelmann,[3287] Vaihinger,[3288] Varičak,[3289] Le Verrier,[3290] argumentation between Vicaire and Mansion,[3291] Vogt,[3292] Voigt,[3293] Volkmann,[3294] Volterra,[3295] Voss,[3296] Wacker,[3297] Waterston,[3298] H. Weber,[3299] L. Weber,[3300] Wilhelm Weber,[3301] Weissenborn,[3302] Whewell,[Dingler p. 149] Wiechert,[3303] Wilkens,[3304] Wilson, Tolman and Lewis,[3305] Wulf,[3306] Wundt,[3307] Zalewski,[3308] Zehnder,[3309] Zenneck,[3310] Ziegler,[3311] Zöllner,[3312] [Copernicus, Kepler, Galileo, Des Cartes, Huyghens, Newton, Leibnitz, Lagrange, Poisson, Hamilton, etc.]?

For histories on, discussions of, and references for, the general theory of relativity, see: Wolfgang Pauli, *Encyklopädie der mathematischen Wissenschaften*, 5, 2, 19, pp. 539-775, English translation by G. Field, *Theory of Relativity*; Oppenheim and Kottler, *Encyklopädie der mathematischen Wissenschaften*, 6, 2, 22 and 22a, pp. 81-237; Sir Edmund Whittaker's *A History of the Theories of Aether and Electricity*, Volume 2; Mehra's *Einstein, Hilbert, and the Theory of Gravitation*; Roseveare's *Mercury's Perihelion, from Le Verrier to Einstein*; and Prof. A. A. Logunov's *The Theory of Gravity*.

One may rightly ask, what, exactly, did Einstein contribute to the theory? Where, in the historic record, do we find Einstein's contribution with established priority? Is the priority Einstein's, merely because he claimed it, in spite of the dates of publication? Given the above list of names, which, while long, is by no means complete, why did Einstein pretend that he created the general theory of relativity? Why didn't Einstein provide references to at least a handful of the above authors and their works? Your author intends to publish a properly referenced version of the Einsteins' major papers on the theory of relativity. There is very little that is novel in their efforts—certainly *nothing* revolutionary.

Why did Einstein submit a nonsensical paper after his divorce, which confused renowned scientists?[3313] Was he not a great independent thinker? Is it possible that Einstein wasn't a genius and became so full of himself that he attempted to go it alone, and failed miserably?

Of course, the "great man", as he once called himself,[3314] was never short of material to steal when he choose to plagiarize. People from around the world wrote to him with their ideas.[3315] The thief held the keys to the vault!

Einstein evinced a career long pattern of publishing "novel" theories and formulæ after others had already published similar words, then claimed priority for himself. He did it with $E = mc^2$. He did it with the so-called special theory of relativity and he did it with the general theory of relativity. Einstein often simply changed the names for terms, then claimed that he had created a new theory, as if Einstein had called red, “blue”, and claimed to have discovered a new color. Harris A. Houghton wrote in the *New York Times* on 21 April 1923,

> “[T]hat the time is still not yet ripe either to conclude that Einstein’s theory is correct or that Professor Einstein should receive much credit for calling something by a different name from that by which it has been previously designated.”[3316]

Einstein built a career out of hype and plagiarism. Arvid Reuterdahl called him, “the Barnum of science.”

Einstein become a hero to many and in their minds a demi-god, seemingly the Holy Ghost incarnate, communicating God’s thoughts to man. The scientific community and the media promote Einstein as the genius who figured it all out. Do we need such heroes? Einstein is seemingly awarded credit for every scientific advancement and theory from the time of Newton up until Einstein’s death. Does Einstein deserve that credit? Is Einstein’s image more important than the progress of science, the natural rights of scientists to question his theories and the history behind them without being smeared, and the right of the public to know the truth?

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2845. S. Newcomb, "On the Definition of the Terms Energy and Work", *Philosophical Magazine*, Series 5, Volume 27, (1889), pp. 115-117. ***See also:*** J. R. Schütz, "Das Prinzip der absoluten Erhaltung der Energie", *Nachrichten von der Königlichen Gesellschaft der Wissenschaft und der Georg-Augusts-Universität zu Göttingen, Mathematisch-Physikalische Klasse*, (1897), pp. 110-123. ***See also:*** G. F. Helm, *Die Energetik nach ihrer geschichtlichen Entwickelung*, Veit, Leipzig, (1898), p. 362.
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