it is still more fatal to Darwin's working hypothesis of adaptation through survival of variations in any degree subject to chance. First, chance is absolutely eliminated, both theoretically and actually, by Proboscidean evolution; second, the rapidity of evolution is now known to be entirely independent of the rapidity of selection. In the Pleistocene million year period extremely slow-breeding elephantoids evolve their grinding teeth with amazing rapidity, far outstripping any of their rapidly breeding mammalian contemporaries in which it is difficult to distinguish a Lower Pleistocene specific stage from a modern specific stage.

We must confess that Biology is at present a totally uncoordinated science still in its infancy. It is not a science in the sense of astronomy or physics or chemistry. As compared with astronomy, it is what astronomy would be if, after the discovery of the spectroscope, the whole structural astronomy had been abandoned. In other words, when we biologists abandon morphology, as a great majority are doing, we are leaving out of consideration the phenotypic aspects of heredity. Certainly no one could dream of the creative evolution of the germ plasm without the aid of the penetrating secular vision of modern vertebrate paleontology.

SPACE STRUCTURE AND MOTION. II

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If we carry out the dynamic description of motion to its logical end, we arrive at rather puzzling conclusions. Let us use a reference system fixed to the earth.

MACH'S PRINCIPLE

The celestial bodies cause a turning of the plane of motion of Foucault's pendulum. *When a street car stops and I feel a jerk, I conclude that there would be no jerk at all, or only a small jerk, if the distant galaxies were not there.* This is a consequence of our dynamic conception that all motion is relative to matter. This principle was first enunciated by Ernst Mach.

Is there anything wrong in our deductions? Some authorities think that matter may perhaps only be responsible for the distortions in space-time and not for its fundamental properties. Weyl[4] has written an interesting dialogue about this subject. But most authorities defend Mach's principle and maintain that the stars are responsible for all the metrical properties of space-time, including inertia.

To understand this action at inconceivable distances we must greatly extend our study. We have, in the writer's opinion, to go deep down into the dark corridors of the foundation of matter. We must also include a new, but not unfamiliar, element in our study.

INTRODUCTION OF THE OBSERVER

In the introduction I enumerated the elements which enter into our description of motion, but I omitted one very important factor. There is also the human observer with his peculiar habit of describing, analyzing and interpreting his sensations and measurements, not as complexes, but in terms of simple, not further reducible elements.

Most human observers have an inherent love for simplicity, uniformity and permanence, and express these concepts in terms of unchanging physical laws of the simplest possible kind valid for the whole universe. If he finds that he can "explain" nature in such a way he prefers this explanation and disregards more complex conceptions, or at least suspects them of being artificial, only usable for giving numerical relations. For this reason he has some preference for inertial reference frames and Euclidean geometry. That is the reason he thinks the earth moves around its axis and not the stellar frame around the earth; the earth moves about the sun and not the sun about the earth. He is influenced by the smallness of the earth as compared with the immensity of the system of galaxies, and ascribes more reality and importance to a frame where the sum total of energy and momenta in the observable universe is comparatively small than to one in which it is tremendously much greater.

Back of the human observer's analysis lies also a peculiar characteristic of his consciousness, which makes him single out one particular axis in space-time, which he calls the time-axis. He regards this as being built up of small elements, which he calls moments of time. His memory enables him, to a certain extent, to combine these moments into a longer time interval, within which he has a definite feeling of retaining his identity, even if his material structure has been entirely renewed. The extension of the time-axis in one direction, the past, seems also to be of a different nature than the extension in the opposite direction, the future.

[4] Massenträgheit und Kosmos, *Die Naturwissenschaften*, 12: 197, 1924.

EUCLIDEAN GEOMETRY

He has also criteria, expressible in mathematical terms, for a space of the simplest possible kind, that is, characterized by the simplest possible geometry. About the validity of Euclidean geometry Einstein[5] quotes Poincaré: "Euclidean geometry is distinguished above all other imaginable axiomatic geometries by its simplicity. Now since axiomatic geometry by itself contains no assertions as to the reality which can be experienced, but can do so only in combination with physical laws, it should be possible and reasonable—whatever may be the nature of reality—to retain Euclidean geometry. For if contradictions between theory and experience manifest themselves, we should rather decide to change physical laws than to change axiomatic Euclidean geometry."

Einstein comments on this: *"Sub specie aeternitatis,*[6] Poincaré in my opinion is right. The idea of the measuring-rod and the idea of the clock coordinated with it in the theory of relativity do not find their exact correspondence in the real world. It is also clear that the solid body and the clock do not in the conceptional edifice of physics play the part of irreducible elements, but that of composite structures, which may not play any independent part in theoretical physics. But it is my conviction that in the present stage of development of theoretical physics these ideas must still be employed as independent ideas; for we are still far from possessing such certain knowledge of theoretical principles as to be able to give exact theoretical constructions of solid bodies and clocks."

Poincaré's standpoint is generalized by Einstein in the following way. "Geometry (G) predicates nothing about the relations of real things, but only geometry together with the purport (P) of physical laws can do so. Using symbols we may say that only the sum of (G) and (P) is subject to the control of experience. Thus (G) may be chosen arbitrarily, and also part of (P); all these laws are conventions. All that is necessary to avoid contradictions is to choose the remainder of (P) so that (G) and the whole of (P) are together in accord with experience."

COMPARISON BETWEEN KINEMATIC AND DYNAMIC DESCRIPTIONS

The kinematic picture of motion takes into account the observer's conception of time as separated from space. In this picture use is made of the simplest possible geometry, constant in space and time, but the physical laws are empirical, and unrelated. In the dynamic description the geometry is—for an actual observer—empirical, variable in space and time, and the physical laws are rational and interrelated. Both descriptions contain empirical and rational elements, and the combination of both must agree with experience to form a "true" description. *From this point of view the general theory of relativity becomes a powerful method of research, rather than the only true description of motion.* Since we have reason to believe that the distinction between the two opposite directions of the time-axis is not only a property of the human consciousness, but has an even more fundamental nature—as evidenced by the increase of entropy with time—it may well be that the kinematic description expresses more reality than the dynamic description. We may take the laws derived by the use of the research method mentioned and apply them in our kinematic description, and thus obtain a simple, constant geometry, a unique time-axis, and rational laws, although the rational character of the laws is not immediately visible when expressed in such terms.

DIFFERENTIATION BETWEEN SPACE AND TIME

I have pointed out that the main difference between the kinematic and the dynamic description of motion lies in the fact that in the first time is regarded as distinct from space, whereas in the second it merges with the three space dimensions into a four-dimensional space-time manifold. This merging is quite natural when space-time is isotropic and only a few test bodies and an observer are present. But when matter is distributed in space, space-time is no longer isotropic, and the very existence of matter causes—if we want to use a geometry constant for the whole universe—a differentiation between space and time, strongly confirmed by our consciousness. *When we investigate space the natural reference frame is one at rest relative to the matter in the universe; when we investigate the laws of motion the natural frame is one in which a freely falling observer is at rest.* The differentiation between space and time has been recognized by Einstein in his expression for a line-element on a large cosmical scale, although in the world considered by him the matter had no motion, and such a world has been proved to be unstable. The same differentiation occurs in Lemaître's expanding universe, where it is the space-scale only that increases with time. In De Sitter's world there was no matter, but only motion, and hence there was no such differentiation. The unique differentiation between space and time means ultimately the conception of a fundamental unique reference frame for *velocities,* and

[5] "Geometry and Experience," *Sidelights on Relativity,* Methuen, 1922.

[6] "From the point of view of eternity." This is Spinoza's famous expression. His philosophy implies that the value and meaning of any fact are not known unless we know it in all its relations to the system of the universe.

velocities referred to this frame we may call "absolute." We can now answer the question whether accelerations and rotations are "absolute" or "relative." The writer would like to put this answer in the following form.

WORLD-FRAME

There exists a *unique* inertial frame, defined, but only statistically and in a loose way, by the anagalactic star systems. This frame we may call the "world frame." These star systems have limited velocities relative to this frame—either on account of a physical, perhaps original, restriction of the linear and angular momenta of atoms and electrons relative to it;[7] or on account of the observable universe formerly having occupied a smaller volume of space, and exchange of momenta and energy having produced a certain distribution law of the original energies and momenta of atoms and stars; or on account of the escape to more remote regions of space of galaxies of the higher velocities. The frame has a space structure which is modified in the neighborhood of matter, but its large-scale features in space and time are uniform, but not necessarily exactly Euclidean. Whether matter is the cause of the metrical properties of the structure, or if protons and electrons are the "visible" centers of singularities in it, is irrelevant; *matter and structure are simply coexistent and coextensive.* Matter is moving relative to the space structure—the necessity of this conception is most clearly seen in the case of rotation—and so is the observer, who has a material structure. It is only when there is a difference in the motion of the observer and an observed or interposed object that any observable effects are produced. We can then understand the coincidence between the inertial frame and the world frame, so far as rotation is concerned. Accelerations relative to this structure and relative to distant galaxies must obviously be the same, and we are at liberty to call rotations and accelerations "relative" or "absolute," but the former seems only to have a statistical meaning. From this point of view there exists also an "absolute" velocity, but it can only be determined statistically from the radial velocities of extra-galactic objects. The sun's absolute velocity is found to be about 300 km/sec., most of it probably due to motion about the center of the galaxy.[8] Even if the space structure should not extend uniformly far beyond the observed galaxies, it may still define a unique frame for the observable universe.

The objection may be raised that any other inertial frame would have the same properties. If we take the extreme consequences of this idea, however, we may think of the case of an observer moving with a constant velocity, relative to the stars, approaching that of light. On account of aberration all the stars would be in one hemisphere, the pole of which lies in the direction of motion. Parallactic displacements would tend to make the nearer stars quickly pass through a region intermediate between the pole and the "equator." The stars near the pole would have a color far out in the ultra-violet, and the stars near the equator would be invisible, only giving out radiation of long wave-length. The light and the electronic emission of the stars, and above all the penetrating radiation (from interstellar space?), would exert a one-sided pressure, like that produced by a "wind," which could set screws in rotation and would cause a retardation of the motion of the observer.[9] It is quite conceivable that phenomena, perhaps of another type than those contemplated in the special theory of relativity and entirely without measurable effects for small velocities, would in such an extreme case make it possible for the observer to determine what he might call his "absolute" velocity, even without referring it to the stars directly.

ETHER AND SPACE STRUCTURE

The difference between the classical ether and the space structure lies in the conception that the former was a medium "apart from" matter, whereas the latter can be regarded as a medium which is "a part of" matter, or perhaps matter is a peculiar part of it. The former medium transmitted energy and linear and angular momentum, but the latter does not carry energy and momenta, this being done by the singularities according to the rules of quantum mechanics.

The space structure is a very real thing. It can move relative to matter, or rather matter can move relative to it, but this motion is not associated with any energy or momentum and is hence not directly observable. The space structure helps to determine observable events, however, by guiding world-lines in accordance with its characteristics or "potentials," and is in this respect identical with what Einstein has called "the ether of the general theory of relativity." Hence it can be explored by "putting world-lines into it," that is, by sending light signals and particles through it.

[7] There exists a certain peculiarity in the motions of the stars in the galaxy (the asymmetry in stellar motions), which can be explained as due to a velocity restriction in this unique, non-rotating world frame. But the restriction seems in this case mainly to be due to the predominance of circular orbits and to the obvious limitation of velocities of bodies permanently belonging to the galactic system.

[8] The latest determinations are by Hubble, *Proc. of the National Academy*, 15: 168, 1929; and by Oort, *Bulletin Astron. Instit. Netherlands*, 5: 239, 1930.

[9] A little consideration shows that large rotations, like those of the spiral nebulae and the galaxy, are slowly reduced by this action, the lost angular momentum being transferred to the *system* of photons, electrons and stars.

SINGULARITIES IN THE SPACE STRUCTURE

The structure contains several kinds of singularities, all carrying energy and angular and linear momentum. The observations of events in the material world are always caused by singularities imparting energy and momenta to the observer's sense organs or instruments. The conception that the motions of bodies and photons are governed by a structure of space will now be extended to similar phenomena in close neighborhood of the material singularities (electrons, protons, atoms). Electrical forces now play a predominant rôle. We know that certain space-time-mass entities (action, angular momenta) only occur in nature as integral multiples of an ultimate small unit. The time element can be standardized by referring the motions to the world frame, after the laws of motion have been determined by the use of the research method mentioned before. We are then led to the conception that around a singularity of a certain charge and polarity space has a definite fine-structure, a conception justified by a number of observed phenomena. The singularities may have many aspects not belonging to the physical world, but their metrical (space-time) aspect can be mathematically described as a system of "waves" in configuration space (Schrödinger). The fine-structure around a singularity varies rapidly as we approach its center, producing potential walls or shells more and more difficult to penetrate, or to leave if we are between two such shells, but it disappears gradually as we recede from the center, and goes over into a smoothly changing positive or negative increment to the "density of electricity" asymptotically approaching zero at infinity. This extension may be regarded as the "foundation" of the singularity. How the electro-magnetic and the inertio-gravitational phenomena are connected seems to be a mystery, but we have reason to believe that the *general* structure of space is due to the superimposed foundations of all the material singularities in the universe. The physical importance of inertial frames defined by all the star systems now becomes understandable, and we can also see that it is only the lack of homogeneity in the structure which makes possible a determination of the world frame. For any observer the appearance and effect of a "wave system" depend upon its interference with that of the material measuring device, and are hence directly dependent upon the relative motion.

A very simple singularity is a photon, which carries energy and angular and linear momentum, depending upon its frequency and state of polarization. A photon far from matter has the peculiar property that it can not remain stationary, but must move with a definite velocity, relative to the world-frame mentioned, equal to that of light, and resembles in this respect a vortex ring with a fixed axial velocity. A photon can attach itself to an atom, but not to an electron or another photon, and its energy and momenta are then absorbed by the wave system of the atom. Photons can also collide with electrons, protons and atoms and are then scattered, but they can not collide with other photons (in which case we could never have seen the stars distinctly).

INTERFERENCE OF LIGHT

In a source of monochromatic light a large number of photons are emitted practically simultaneously from a large number of excited atoms, due to resonance effects.[10] Such a group of photons constitutes a "crystal shell" moving with the velocity of light, the spacing of the photons in depth depending upon their energy and being equal to one "wave-length." The lateral spacing is governed by a repulsive force between the photons. The photons tend to remain on or near certain "phase surfaces," ordinarily perpendicular to the direction of propagation. When such a coherent crystal meets another coherent crystal of the same wave-length, the photons do not collide but are displaced laterally, and place themselves at the intersections of the phase surfaces. It is only when the two groups are part of the same crystal that an interference pattern fixed in space can be produced. In a similar way we can visualize the interference due to a group of electrons of the same velocity, and thus of the same momenta, surrounded by similar fine-structures and hence of uniform spacing in depth. The "spacing" must not be thought of as being measured accurately by the use of photons or electrons—the uncertainty principle making this impossible—but is measured by a product of a velocity and a periodic time, that is, as a statistical property pertaining to a group.

SPACING OF ATOMS

The compounded fine-structure around the atomic nuclei and electrons in ordinary crystals and other solid bodies determine their spacing, and hence are responsible for the elastic and optical properties of these bodies.[11] The "potential" and the actual spacing of the atoms may differ if the body is subject to a stress. Organic structures are also determined by a fine-structure, and the complex structure and change in living cells indicate thus a highly complicated and

[10] This conception is necessary in order to understand the coherence of light beams and the existence of interference for very weak light.

[11] Electro-magnetic forces are here regarded as due to the space gradient in the combined fine-structure, and are dependent upon the relative positions, motions and polarities of all the charges present. The forces on the atomic nuclei in a crystal hence disappear when the nuclei are near certain singular points representing stationary values of the density of electricity.

changing fine-structure at that particular place and time. If we judge from the physical properties of its constituent atoms and molecules alone, living organisms are, in contradistinction to crystals, extremely improbable and should not exist at all, and it seems to the writer that we may well be forced to the conception that the spacing of the molecules in living cells is not directly determined by any grouping of atoms, however complicated, but by an *independent* fine-structure in space, which only slightly modifies the ordinary motions of electrons and atoms. To secure stable "materialization," growth and development of the minute structure in an egg-cell, for instance, it seems that aggregation of atoms must first be "trapped" in certain singular points in the immaterial fine-structure. This can only happen if the vibration system of the aggregate moving through it harmonizes with the existing structure. For this purpose the aggregate must have the right mass, charge and structure, the polarities must be correct, and it must move slowly in a liquid—like atoms when forming a crystal from a solution—so that the weak electric forces due to the fine-structure can effectively stop it, and it is then incorporated in the immaterial (mass- and inertia-free) fine-structure (assimilation).

We living beings can, if we so choose, change the potential spacing of atoms within the cells of our muscles and do work, but the energy must come from a source other than the mental will or the nerve impulse. We are also familiar with a whole world of other phenomena, associated with space and time, but not directly with mass, energy or momenta.

CONCLUSION

It was the pull of the intangible threads binding my material body to the space structure, the latter being in itself the foundation of the innumerable atoms in the innumerable galaxies, I felt when my street car stopped. It was the same pull, due to a horizontal stratification in the superimposed foundations of the atoms in the near-by earth I felt when I raised my hand. In doing this I sent weak electric currents through certain nerves to the muscles in my arm, which caused a modification of the potential spacing of the atoms in the individual cells. The contraction of the muscles required work, and this was mostly taken from organized chemical energy.[12] The small energy needed for the nerve impulse was similarly supplied by chemical action in the brain cells. I noticed a time lag and an element of freedom to do or not to do it, which I imagined was due to the fact that the original action in the brain cells was entirely energy-free. It did not belong to the ordinary physical world of atoms, ruled by probabilities, but belonged to another world, with which I was also familiar, but only on a gross scale, where individual bodies were moved according to a plan, the energy being taken from a source external to the designer.

A large number of photons, which, starting eight minutes earlier from the sun, were reflected by my hand, had at the emission process arranged themselves in a peculiar moving pattern, which made possible the formation of a distinct image of my hand on the retina of my eye. The vibrations in the space structure in a certain part of my brain caused by this image had also another and much more fundamental aspect and represented in my consciousness a visual sensation. When I reflected over this, and over the existence of organic and, in particular, human life as indicative of the method by which a development of something immaterial is brought about for an unknown ulterior purpose, the space structure in other parts of my brain also vibrated. Another vibration and I felt an intensive joy, like that of a man, born and kept in the dungeons of a prison, who has just seen a ray of light coming through the impenetrable prison walls revealing a little bit of a mysterious sunlit world.

OBITUARY

RECENT DEATHS

THE death is announced, at the age of seventy-seven years, of Dr. Erasmus Haworth, formerly dean of the school of geology at the University of Kansas and for many years state geologist.

DR. HEINRICH HASSELBRING, chief of the department of botany, Central Experiment Station, Santiago de las Vegas, Cuba, from 1907 to '09, and physiologist in the United States Bureau of Plant Industry from 1909 until his retirement for disability a short time ago, died on November 9 at the age of fifty-seven years.

SIR DUGALD CLARK, known for his work on internal combustion engines and the properties and possibilities of gaseous fuel and gas lighting and heating, died on November 12, in his seventy-ninth year.

[12] The conditions may be similar to those in a voltaic pile, where we also have organized chemical energy and where the electric attraction between the plates may represent the contractive force. But we must not overlook the possibility that some of the energy may come from disorganized motions (heat) of the atoms. Although this is a contradiction of the second law of thermodynamics, we must remember that we are dealing with an action on an atomic scale. It seems to the writer quite possible that atoms also here may be "trapped" in certain singular points of the modified fine-structure.