Chapter 1 : Matter - Wikipedia

modern views on matter The nature of matter has been regarded by philosophers from many points of view, but it is not from any philosophic standpoint that I presume in this University to ask you to consider the subject under my guidance.

This lesson should take two minute class periods. Motivation Briefly review and discuss what students learned in The History of the Atom 4. After reading and interacting with the work of J. Thomson, students were able to follow along on the first critical scientific adventure into the inner world of the atom and the discovery of the electron. In this final lesson, they will learn of the greater role that bigger and more advanced instruments like accelerators have taken in advancing the study of modern atomic theory. It might be worth noting that Thomson and others had a critical hand in the kinds of computer technology, TVs, and other scientific enterprises that humanity enjoys and lives on today. As with other scientific discoveries, students should be reminded that Thomson had plenty of help and was able to make and confirm his discoveries through the work of countless other scientists e. Explain to students that, since the discovery of the electron in , modern atomic theory has advanced considerably. These and other findings have led to a Standard Model, which scientists hope will one day explain in great detail the structure and stability of all matter. Further research has uncovered the following: Students of all ages show a wide range of beliefs about the nature and behavior of particles. Despite these difficulties, there is some evidence that carefully designed instruction carried out over a long period of time may help middle-school students develop correct ideas about particles. Benchmarks for Science Literacy, pp. Class One Students should use The Modern Theory student esheet to go to and read each section of Electrons in Atoms , a chronological timeline marking milestones from to the present in the advancement of atomism since the electron. Depending on your preferences, you may either have students read on their own or as a class, where time is taken after each section to pose questions and discuss the significance of the electron-related discoveries and inventions. Once the material has been covered, assign the Electrons in Atoms student sheet, either as an assignment or quiz. Answers are provided on the Electrons in Atoms teacher sheet. To begin, students should read A Summary of Particle Physics , which briefly describes the evolution of particle physics from the early s to the present. This section covers both the history and science of particles. While it is important to keep the focus on the history, you may choose to emphasize the scientific particle basics, depending on your purpose and the level of your students. Use the questions on the Particle Physics teacher sheet to guide your discussion after students finish reading. Next, direct students to read and review the Particle Physics Timeline section of the site, specifically the final two sections: Quantum Theory and â€”Present: The Modern View the Standard Model. While these timeline sections cover the evolution of atomic theory since the Greeks, students should focus on these last two modern sections, which cover the advent of the quantized atom, leading to the recent theory of the Standard Model. Before students begin reading the specific chronological events in each area, point out or paraphrase the helpful introductions in each section, which help to briefly summarize the history of subatomic development since J. They are as follows: Quantum Theoryâ€” to At the start of the twentieth century, scientists believed that they understood the most fundamental principles of nature. Atoms were solid building blocks of nature; people trusted Newtonian laws of motion; most of the problems of physics seemed to be solved. Of particular interest was the growing field of quantum mechanics, which completely altered the fundamental precepts of physics. Over the last thirty years, the theory that is now called the Standard Model of particles and interactions has gradually grown and gained increasing acceptance with new evidence from new particle accelerators. After students read and discuss these important events in the development of modern atomic theory, use the questions on the teacher sheet as a basis to review the material and pique their interest Finally, depending on the time that remains, encourage students to go through the first three areas of the Particle Adventure: This will give students a simple, colorful, interactive, and fundamental review of what they have learned in this lesson and the other lessons in The History of the Atom series. If little or no time remains, encourage students to read through these and other sections as part of their Extensions. Assessment Assign an essay where students explain in their own words how our modern understandings of the atom have evolved over the years due to the contributions of many people. You may have them begin with the ancient Greeks or with J. While addressing key developments during this period, students should touch on the ongoing goals underlying this scientific pursuit, as well as the kinds of questions and issues that remain for present and future scientists in the area of modern atomic theory. Students could explore other parts of The Particle Adventure website, including: Other sections include current developments and the potential of future discoveries. Seeing with Electrons is an extended exhibit that provides students with a broader understanding of the various types of instruments and applications in life that electrons have inspired.

DOWNLOAD PDF MODERN VIEWS ON MATTER.

Chapter 2 : Modern View of Matter - Mind Map

Modern Views on Matter Delivered in the Sheldonian Theatre, Oxford, June 12, by Oliver Lodge Electrons, or the Nature and Properties of Negative Electricity by Sir Oliver Lodge The Recent Development of Physical Science by William Cecil Dampier Whetham.

This search for certainty went with a swinging back of the pendulum in science itself from the vitalism of the previous period to the materialism of the mid-century. German philosophers derided idealism and taught the equivalence of consciousness and chemistry: A slight modification is to allow the voidâ€"or empty spaceâ€"to exist also in its own right. These objects interact in the sort of way that stones do: The theory denies that immaterial or apparently immaterial things such as minds exist or else explains them away as being material things or motions of material things. Types distinguished by departures from the paradigm In modern physics if interpreted realistically , however, matter is conceived as made up of such things as electrons , protons , and mesons , which are very unlike the hard, massy, stonelike particles of mechanical materialism. In it the distinction between matter and energy has also broken down. It is therefore natural to extend the word materialist beyond the above paradigm case of mechanical materialism to cover anyone who bases his theory on whatever it is that physics asserts ultimately to exist. This sort may be called physicalistic materialism. Such a materialist allows the concept of material thing to be extended so as to include all of the elementary particles and other things that are postulated in fundamental physical theoryâ€"perhaps even continuous fields and points of space-time. Inasmuch as some cosmologists even try to define the elementary particles themselves in terms of the curvature of space-time, there is no reason why a philosophy based on such a geometricized cosmology should not be counted as materialist, provided that it does not give an independent existence to nonphysical things such as minds. Still another departure from the paradigm is the theory that holds that everything is composed of material particles or physical entities generally but also holds that there are special laws applying to complexes of physical entities, such as living cells or brains , that are not reducible to the laws that apply to the fundamental physical entities. To avoid inconsistency, such a theory may have to allow that the ordinary laws of physics do not wholly apply within such complex entities. Another common relaxation of the paradigm is that which allows as compatible with materialism such a theory as epiphenomenalism , according to which sensations and thoughts do exist in addition to material processes but are nonetheless wholly dependent on material processes and without causal efficacy of their own. A form of double-aspect theory in which these properties were allowed to be causally effective would be a species of emergent materialism. Of course, more than one of these qualifications might be made at the same time. Type distinguished by its view of history In the wider world, however, the word materialism may bring to mind dialectical materialism , which was the orthodox philosophy of communist countries. This is most importantly a theory of how changes arise in human history , though a general metaphysical theory lies in the background. They seem to hold merely that mental processes are dependent on or have evolved from material ones. Though they might be akin to emergent materialists, it is hard to be sure; their assertion that something new emerges at higher levels of organization might refer only to such things as that a computer is different from a mere heap of its components. And if so, even an extreme physicalistic materialist could acquiesce in this view. The distinctive features of dialectical materialism would thus seem to lie as much in its being dialectical as in its being materialist. Its dialectical side may be epitomized in three laws: Nondialectical philosophers find it hard, however, to interpret these laws in a way that does not make them into either platitudes or falsehoods. Perhaps because of the historical determinism implicit in dialectical materialism, and perhaps because of memories of the mechanical materialist theories of the 18th and 19th centuries, when physics was deterministic, it is popularly supposed that materialism and determinism must go together. This is not so. As indicated below, even some ancient materialists were indeterminists , and a modern physicalist materialism must be indeterministic because of the indeterminism that is built into modern physics. Modern physics does imply, however, that macroscopic bodies behave in a way that is effectively deterministic, and, because even a single neuron nerve fibre is a macroscopic object by quantum-mechanical standards, a physicalistic materialist may still regard the human brain as coming near to being a mechanism that behaves in a deterministic way. Types distinguished by their account of mind A rather different way of classifying materialist theories, which to some extent cuts across the classifications already made, emerges when the theories are divided according to the way in which a materialist accounts for minds. A central-state materialist identifies mental processes with processes in the brain. An analytical behaviourist , on the other hand, argues that, in talking about the mind, one is not talking about an actual entity, whether material e. According to the analytical behaviourist, there is no more of a problem for the materialist in having to identify mind with something material than there is in identifying such an abstraction as the average plumber with some concrete entity. Analytical behaviourism differs from psychological behaviourism , which is merely a methodological program to base theories on behavioral evidence and to eschew introspective reports. Epistemic materialism is a theory that can be developed either in the direction of central-state materialism or in that of analytical behaviourism and that rests on the contention that the only statements that are intersubjectively testable are either observation reports about macroscopic physical objects or statements that imply such observation reports or are otherwise logically related to them. Before leaving this survey of the family of materialistic theories, a quite different sense of the word materialism should be noted in which it denotes not a metaphysical theory but an ethical attitude. A person is a materialist in this sense if he is interested mainly in sensuous pleasures and bodily comforts and hence in the material possessions that bring these about. A person might be a materialist in this ethical and pejorative sense without being a metaphysical materialist, and conversely. An extreme physicalistic materialist, for example, might prefer a Beethoven recording to a comfortable mattress for his bed; and a person who believes in immaterial spirits might opt for the mattress. Leucippus is known only through his influence on Democritus. According to Democritus, the world consists of nothing but atoms indivisible chunks of matter in empty space which he seems to have thought of as an entity in its own right. These atoms can be imperceptibly small, and they interact either by impact or by hooking together, depending on their shapes. The great beauty of atomism was its ability to explain the changes in things as due to changes in the configurations of unchanging atoms. The view may be contrasted with that of the earlier philosopher Anaxagoras , who thought that when, for example, the bread that a person eats is transformed into human flesh, this must occur because bread itself already contains hidden within itself the characteristics of flesh. Democritus thought that the soul consists of smooth, round atoms and that perceptions consist of motions caused in the soul atoms by the atoms in the perceived thing. He differed from Democritus in that he postulated an absolute up-down direction in space, so that all atoms fall in roughly parallel paths. To explain their impacts with one another, he then held that the atoms are subject to chance swervesâ€”a doctrine that was also used to explain free will. His ethics , however, was not materialistic in the pejorative sense of the word. Modern materialism Materialism languished throughout the medieval period , but the Epicurean tradition was revived in the first half of the 17th century in the atomistic materialism of the French Roman Catholic philosopher Pierre Gassendi. In putting forward his system as a hypothesis to explain the facts of experience, Gassendi showed that he understood the method characteristic of modern science, and he may well have helped to pave the way for corpuscular hypotheses in physics. Gassendi was not thoroughgoing in his materialism inasmuch as he accepted on faith the Christian doctrine that people have immortal souls. His contemporary, the English philosopher Thomas Hobbes , also propounded an atomistic materialism and was a pioneer in trying to work out a mechanistic and physiological psychology. He also propounded a hedonistic ethics as well as an uncompromising atheism , which provoked a reply even from the Deist Voltaire. Courtesy of the National Portrait Gallery, London The 18th-century French materialists had been reacting against orthodox Christianity. The latter is notorious for his assertion that the brain secretes thought just as the liver secretes bile. This metaphor of secretion, previously used by P. Cabanis , a late 18th-century French materialist, is no longer taken seriously, because to most philosophers it does not make sense to think of thought as a stuff. The synthesis of urea the chief nitrogenous end product of protein metabolism , discovered in , broke down the discontinuity between the organic and the inorganic in chemistry , which had been a mainstay of nonmaterialistic biology. There still seemed to be a gap, however, between the living and the nonliving, though E. Haeckel , a 19th-century German zoologist, thought that certain simple organisms could have been generated from inorganic matter and, indeed, that a certain simple sea creature may well be in process of generation in this way even now. Though Haeckel was wrong, 20th-century biologists proposed much more sophisticated and more plausible theories of the evolution of life from inorganic matter. Haeckel and his contemporary, the British zoologist T. Huxley , did much to popularize philosophical accounts of the world that were consonant with the scientific thought of their time, but neither could be regarded as an extreme materialist. Twentieth-century materialism Perhaps because modern developments in biochemistry and in physiological psychology greatly increased the plausibility of materialism, there was in the midth century a resurgence of interest in the philosophical defense of central-state materialism. Central-state materialists proposed their theories partly because of dissatisfaction with the analytical behaviourism of the Oxford philosopher Gilbert Ryle. Nevertheless, it would seem that analytical behaviourism could be used to support a physicalist materialism that would go on to explain human behaviour by means of neural mechanisms. Ryle himself was suspicious of mechanistic accounts of biology and psychology. Analytical behaviourism was felt to be unsatisfactory, however, chiefly because of its account of introspective reports as avowals see above Types distinguished by their account of mind , which most philosophers found to be unconvincing. Philosophers distinguished two forms of central-state materialism, namely, the translation form and the disappearance form. The disappearance form is the view that such a translation cannot be done and that this fact, however, does not refute physicalism but shows only that ordinary introspective reports are contaminated by false theories. Translation central-state theories Among the philosophers who advocated the translation form was the American philosopher Herbert Feigl , earlier a member of the Vienna Circle , who, in an influential monograph, did the most to get contemporary philosophers to treat central-state materialism as a serious philosophical theory. The objection confuses meaning and reference. Against the objection that a purely physical process a dance of electrons, protons, and so on cannot have the sensory quality of greenness that is observed in a visual experience of seeing grass, say, they replied that to talk of the sensory experience of something looking green or having a green mental image is not to talk of anything that is literally green, but is simply to report that some internal process is of the sort that normally goes with seeing something, such as a lawn, which really is green. The analysis of the introspective report is neutral between these two contentions; the materialist, however, opts for his contention on various grounds. The British materialist U. Place did so on the ground of normal scientific methodology; and the Australian materialist J. A physicalistic materialist has, of course, an obligation to go on to give a suitable account of such apparently nonphysicalist qualities as the greenness of grass. At one time Smart analyzed colours in terms of the discriminatory behaviour of human beings. Another Australian materialist, D. Armstrong , held, on the other hand, that colours are as a matter of fact properties of objects, such properties being of the sort describable in the theoretical terms of physics. Feigl, in turn, was to some extent and rather reluctantly a double-aspect theorist. He qualified the position taken by the other translation theorists, conceding that the translations do leave something outâ€”viz. He held, however, that such properties are irrelevant to causal explanations of phenomena. The translation form of central-state materialism thus had some affinities with the earlier epistemic materialism of the logical positivist philosophers Rudolf Carnap and Hans Reichenbach. Thus, Carnap suggested that mental predicates be treated as applying to material entities: Lewis , an American philosopher of science and language, developed a translation form of central-state materialism on the basis of a theory regarding the definition of theoretical terms in science. According to this theory, entities such as electrons, protons, and neutrons are defined in terms of the causal roles that they play in relation to observational phenomenaâ€”e. Lewis applied this account to commonsense psychology. Since mental entities, such as pains, are defined in commonsense psychology in terms of their causal roles in relation to observable behaviour and since there is empirical reason to ascribe the same causal roles to brain processes, Lewis identified mental events, processes, and states with brain events, processes, and states. Courtesy of Princeton University, Princeton, New Jersey Disappearance central-state theories The disappearance form of central-state materialism was held by P. Feyerabend , an American philosopher, who denied that the materialist can give a neutral analysis of introspective reports. He argued, however, that this admission does not show the untenability of materialism. The influential American philosophers W. In the case of Quine, there is a certain Platonism in that he believes in the objective reality of some abstract , or nonspatiotemporal, entitiesâ€"viz. On the whole, materialism is contrary to the spirit of both Indian and traditional Chinese philosophy , though the Carvaka school of materialists flourished from the 6th century bce until medieval times in India. Substantive issues in materialism Reductionism , consciousness, and the brain The main attraction of materialism is the way in which it fits in with a unified picture of scienceâ€"a picture that has become very plausible. Thus, chemistry is reducible to physics inasmuch as there is a quantum-mechanical theory of the chemical bond. Biology is mainly an application of physics and chemistry to the structures described in natural history including the natural history that one can explore through powerful microscopes. Increasingly, biological explanations resemble explanations in engineering , in which material structures are described and then the laws of physics and chemistry are used to explain the behaviour of these structures. In the biological case, of course, these structures are often dynamic in the sense that their molecules are continually being replaced.

Chapter 3 : The History of the Atom 5: The Modern Theory - Science NetLinks

Modern Views on Matter Delivered in the Sheldonian Theatre, Oxford, June 12, by Oliver Lodge Space-Time-Matter by Hermann Weyl The Recent Development of Physical Science by William Cecil Dampier Whetham.

These new particles may be high-energy photons gamma rays or other particleâ€”antiparticle pairs. The resulting particles are endowed with an amount of kinetic energy equal to the difference between the rest mass of the products of the annihilation and the rest mass of the original particleâ€”antiparticle pair, which is often quite large. Depending on which definition of "matter" is adopted, antimatter can be said to be a particular subclass of matter, or the opposite of matter. Antimatter is not found naturally on Earth, except very briefly and in vanishingly small quantities as the result of radioactive decay , lightning or cosmic rays. This is because antimatter that came to exist on Earth outside the confines of a suitable physics laboratory would almost instantly meet the ordinary matter that Earth is made of, and be annihilated. Antiparticles and some stable antimatter such as antihydrogen can be made in tiny amounts, but not in enough quantity to do more than test a few of its theoretical properties. There is considerable speculation both in science and science fiction as to why the observable universe is apparently almost entirely matter in the sense of quarks and leptons but not antiquarks or antileptons , and whether other places are almost entirely antimatter antiquarks and antileptons instead. In the early universe, it is thought that matter and antimatter were equally represented, and the disappearance of antimatter requires an asymmetry in physical laws called CP charge-parity symmetry violation , which can be obtained from the Standard Model, [46] but at this time the apparent asymmetry of matter and antimatter in the visible universe is one of the great unsolved problems in physics. Possible processes by which it came about are explored in more detail under baryogenesis. Formally, antimatter particles can be defined by their negative baryon number or lepton number , while "normal" non-antimatter matter particles have positive baryon or lepton number. In October , scientists reported further evidence that matter and antimatter , equally produced at the Big Bang , are identical, should completely annihilate each other and, as a result, the universe should not exist. Conservation of matter Two quantities that can define an amount of matter in the quarkâ€”lepton sense and antimatter in an antiquarkâ€”antilepton sense , baryon number and lepton number , are conserved in the Standard Model. Even in a nuclear bomb, none of the baryons protons and neutrons of which the atomic nuclei are composed are destroyedâ€”there are as many baryons after as before the reaction, so none of these matter particles are actually destroyed and none are even converted to non-matter particles like photons of light or radiation. Instead, nuclear and perhaps chromodynamic binding energy is released, as these baryons become bound into mid-size nuclei having less energy and, equivalently , less mass per nucleon compared to the original small hydrogen and large plutonium etc. Even in electronâ€”positron annihilation , there is no net matter being destroyed, because there was zero net matter zero total lepton number and baryon number to begin with before the annihilationâ€”one lepton minus one antilepton equals zero net lepton numberâ€”and this net amount matter does not change as it simply remains zero after the annihilation. Other types Pie chart showing the fractions of energy in the universe contributed by different sources. Ordinary matter is divided into luminous matter the stars and luminous gases and 0. Ordinary matter is uncommon. Modeled after Ostriker and Steinhardt. Vertical axis is speed of rotation about the galactic center. Horizontal axis is distance from the galactic center. The sun is marked with a yellow ball. The observed curve of speed of rotation is blue. The predicted curve based upon stellar mass and gas in the Milky Way is red. The difference is due to dark matter or perhaps a modification of the law of gravity. Dark matter See also: Galaxy formation and evolution and Dark matter halo In astrophysics and cosmology , dark matter is matter of unknown composition that does not emit or reflect enough electromagnetic radiation to be observed directly, but whose presence can be inferred from gravitational effects on visible matter. The commonly accepted view is that most of the dark matter is non-baryonic in nature. Perhaps they are supersymmetric particles , [61] which are not Standard Model particles, but relics formed at very high energies in the early phase of the universe and still floating about. Its precise nature is currently a mystery, although its effects can reasonably be modeled by assigning matter-like properties such as energy density and pressure to the vacuum itself. Twenty-six percent is dark matter. So less than 1 part in 20 is made out of matter we have observed experimentally or described in the standard model of particle physics. The Trouble with Physics, p. Exotic matter Exotic matter is a concept of particle physics , which may include dark matter and dark energy but goes further to include any hypothetical material that violates one or more of the properties of known forms of matter. Some such materials might possess hypothetical properties like negative mass. Historical development Antiquity c. Anaximenes flourished BC, d. All of these notions had deep philosophical problems. Rather they, like everything else in the visible world, are composed of the basic principles matter and form. For my definition of matter is just thisâ€"the primary substratum of each thing, from which it comes to be without qualification, and which persists in the result. In other words, in contrast to the early modern conception of matter as simply occupying space, matter for Aristotle is definitionally linked to process or change: For example, a horse eats grass: The matter is not specifically described e. Matter in this understanding does not exist independently i. It can be helpful to conceive of the relationship of matter and form as very similar to that between parts and whole. For Aristotle, matter as such can only receive actuality from form; it has no activity or actuality in itself, similar to the way that parts as such only have their existence in a whole otherwise they would be independent wholes. He was primarily a geometer. Instead of, like Aristotle, deducing the existence of matter from the physical reality of change, Descartes arbitrarily postulated matter to be an abstract, mathematical substance that occupies space: So, extension in length, breadth, and depth, constitutes the nature of bodily substance; and thought constitutes the nature of thinking substance. Descartes makes an absolute distinction between mind, which he defines as unextended, thinking substance, and matter, which he defines as unthinking, extended substance. In short, Aristotle defines matter roughly speaking as what things are actually made of with a potential independent existence , but Descartes elevates matter to an actual independent thing in itself. In both conceptions, matter is passive or inert. In the respective conceptions matter has different relationships to intelligence. For Aristotle, matter and intelligence form exist together in an interdependent relationship, whereas for Descartes, matter and intelligence mind are definitionally opposed, independent substances. In the third of his "Rules of Reasoning in Philosophy", Newton lists the universal qualities of matter as "extension, hardness, impenetrability, mobility, and inertia". Like Descartes, Newton rejected the essential nature of secondary qualities. Carrying the logic forward more consistently, Joseph Priestley â€" argued that corporeal properties transcend contact mechanics:

Chapter 4 : Modern Views on Matter

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It is because new views as to the structure and properties of what used to be called the ultimate atom are now being born, and because these views, whether they succeed in ultimately establishing themselves in every detail or not, are of surpassing interest, that I have chosen this very recently deciphered chapter of science as the subject-matter for the lecture to be given this year in remembrance of a man whom I knew as a friend, and whose mind, if he had been alive to-day, would have been widely open to these most modern developments of Physical Science. Nor would the admittedly speculative character of some of the hypotheses now being thrown out have deterred him from hearing about them with the keenest interest. If I may venture to say so, it is the more philosophical side of Physics which has always seemed to me most suitable for study in this University; and although I disclaim any competence for philosophic treatment in the technical sense, yet I doubt not that the new views, in so far as they turn out to be true views, will have a bearing on the theory of matter in all future writings on Philosophy; besides exercising a profound effect on the pure sciences of Physics and Chemistry, and perhaps having some influence on certain aspects of Biology also. In admitting that I am going to promulgate a speculative hypothesis, that is a hypothesis for which there is evidence but not yet conclusive evidence, I must not lead you to suppose that the whole of what I have to say is of this character. On the contrary, much of it is certain, that is to say is accepted by a consensus of opinion to-day among those who by reason of study are competent to judge. I will endeavour carefully to discriminate between what is in this sense certain and what must still be regarded as doubtful and needing further support. To treat the subject properly, to give all the evidence as well as the results, would need a volume, or a course of lectures; and in order to be brief I must frequently be dogmatic, but I shall only intend to be so in those places where I feel sure that the physicists present will agree with me. When I have a dogma of this kind to propound I shall call it a thesis. The more speculative opinions I shall plainly denominate hypotheses. My first thesis is that an electric charge possesses the most fundamental and characteristic property of matter, viz. In order to have any appreciable mass, however, an electric charge must either be extremely great or must be extremely concentrated; and, unless it is to be utterly masked by the matter with which it is associated, it must be the latter: The mass or inertia of a charge depends upon two factorsâ€”the quantity of electricity in it, and its potential,â€”and by concentrating a given charge on to a sufficiently small sphere, the latter factor can be raised theoretically to any value we please, and thus any required inertia can be obtained; unless a stage is reached at which it becomes physically impossible to concentrate it any more. The next thesis is a very simple and familiar one, and dates virtually from the time of Faraday, though the conception has gradually gained in clearness and solidity: Now mathematical data were given by J. Every electric charge is to be thought of as due to the possession of a number of electrons, but a fraction of an electron is at present considered impossible, meaning that no indication of any further subdivision has ever loomed even indistinctly above the horizon of practical or theoretical possibility. The electrification of an atom of matter consists in attaching such an electron to it, or in detaching one from it. An atom of matter possessing an electron in. This inversion in the natural use of the names positive and negative is inconvenient but accidental and not really serious; it dates from the time of Benjamin Franklin. These ions or travelling particles of matter have been long known. A liquid or a gas conducts because of the locomotion of its charged particles. The particles travel in an electric field because of their attached charges, all the positive going one way, and all the negative the other way; and each kind of matter possesses an intrinsic or characteristic ionic velocity, when urged by a given field through a given solution. The charges may be likened to horses or other propelling agency, and the atom to the vehicle or heavy body which is dragged along. The speed of travel through liquids is very slow, but through gases is considerably quicker, partly because there is less resistance, and partly because it is easier to maintain a steep gradient of potential in a medium where the ions are not too numerous. It may be convenient here to emphasize the dimensions of an electron as above specified, for the arguments in favour of that size are very strong though not absolutely conclusive; we are sure that their mass is of the order one-thousandth of the atomic mass of hydrogen, and we are sure that if they are purely and solely electrical their size must be one hundred-thousandth of the linear dimensions of an atom; a size with which their penetrating power and other behaviour is quite consistent. Assuming this estimate to be true, it is noteworthy how very small these electrical particles are, compared with the atom of matter to which they are attached. If an electron is represented by a sphere an inch in diameter, the diameter of an atom of matter on the same scale is a mile and a half. It is well to bear this extreme smallness in mind in what follows. An atom is not a large thing, but if it is composed of electrons, the spaces between them are enormous compared with their size as great relatively as are the spaces between the planets in the solar system. My next thesis is that these electrons or minute charged corpuscles can exist separately, for they can be detached from their atoms of matter at an electrode, not only in electrolytic liquids but also in gases, and when thus released from their thousandfold more massive atom, they fly away from the negative electrode with prodigious speed, because they are acted on by the same electrical propelling force as before, but now have hardly anything to move. These isolated flying particles travel a long distance in rarefied gas, and are known as cathode rays. They were studied by Varley, Hittorf, Crookes, Lenard, and others, both inside and outside vacuum-tubes, and they are now known to be flung off spontaneously from many substances. At first these cathode rays were thought to be atoms of matter, though their extraordinary penetrating power rendered such a hypothesis difficult of belief, and caused Crookes to speak of them as matter in a fourth state. They are, however, certainly energetic bodies, being able to propel light windmills, to heat platinum to redness, and to charge an electroscope; they are also able to penetrate thin sheets of metal and to affect photographic plates or phosphorescent substances on the other side. The final definite establishment of the fact that these flying particles are not atoms of matter, but are bits chipped off the atoms, fractions of an atom as it were, the same identical kind of bits being chipped off every kind of chemical atom, their mass always about one-thousandth of that of a hydrogen atom, and moving under favourable circumstances with something not much less than the speed of light, is due to the researches of Professor J. Thomson and his coadjutors in the Cavendish Laboratory, Cambridge, and represents a long series of measurements devised and executed with consummate skill. I have no time to go into detail concerning these important and elaborate and most interesting investigations. Suffice it to say that portions of them are due to your own Wykeham Professor of Physics, Professor Townsend, working in conjunction and collaboration with others, under the leadership of Professor J. I must not dwell upon the properties and powers of electrons, nor upon the experimental means by which these measurements were made, for it is far too large a subject. I must exhibit a few diagrams, and briefly summarize a few main facts: When shot into a mass of air they dissociate and ionize that air for a time, and render it electrolytically conducting; also of course they can discharge positively electrified bodies themselves, and can thus be most readily detected in small numbers. Electrons in orbital motion have been shown to constitute the mechanism by which atoms are able to radiate light; and a great mass of semi-astronomical facts concerning these orbits and their perturbations have been obtained by immersing the source of light in a strong magnetic field, and observing the minute but very definite changes of spectra thereby produced: Lorentz of Leyden, and Zeeman of Amsterdam, will be inseparably associated. In all these and other ways the electron has become a familiar object. It constitutes the ionic charge of matter. Multiples of it, but no fractions, are possible. Its mass, its charge, and its speed have been frequently measured by different processes, and always with consistent results. It is the most definite and fundamental and simple unit which we know of in nature. It has thus displaced the so-called atom of matter from its fundamental place of indivisibility. The atom of matter has been shown capable of losing an electron, of having at least one chipped off it. The electron has been shown to possess in kind, though not in degree, the fundamental properties of the original atom of which it had formed a part; and it becomes a reasonable hypothesis to surmise that the whole of the atom may be built up of positive and negative electrons interleaved together, and of nothing else; an active or charged ion having one electron in excess or defect, but the neutral atom having an exact number of pairs. The oppositely charged electrons are to be thought of on this hypothesis as flying about inside the atom, as a few thousand specks like full stops might fly about inside this hall; forming a kind of cosmic system under their strong mutual forces, and occupying the otherwise empty region of space which we call the atom,â€”occupying it in the same sense that a few scattered but armed soldiers can occupy a territory,â€"occupying it by forceful activity, not by bodily bulk. The hypothetical part of the statement about the size of an electron is the following. Whereas both the mass and the charge of an electron is known, it is not yet quite certain that the mass is wholly due to the charge. It is possible, but to me very unlikely, that the electron, as we know it, contains a material nucleus in addition to its charge, so in that case it need not be so concentrated, because a portion of its mass would be otherwise accounted for. The mass which is explicable electrically is to a considerable extent understood, but the mass which is merely material whatever that may mean is not understood at all. We know more about electricity than about matter; and the way in which electrical inertia is accounted for electromagnetically and localized in the ether immediately surrounding the nucleus of charge, is comparatively clear and distinct. The chief defect in the electrical theory of matter at present is that the positive electron, if it exists, has never yet been isolated from the rest of an atom of matter. It has never been found detached from a mass less than the hydrogen atom; whereas the negative electron is constantly and freely encountered flying about alone, its mass being little more than the thousandth part of an atom of hydrogen. Until a positive electron can be similarly isolated, the hypothesis that an atom is really composed solely of electricity, that is to say of equal quantities of positive and negative electricity associated together in a certain grouping of little bodies, each of which is nothing more than a concentrated charge of electricity of known amount, must remain a hypothesis. It is a fascinating guess that the electrons constitute the fundamental substratum of which all matter is composed. That a grouping of say electrons, positive and negative, interleaved or interlocked in a state of violent motion so as to produce a stable configuration under the influence of their centrifugal inertia and their electric forces, constitutes an atom of hydrogen. That sixteen times as many, in another stable grouping, constitute an atom of oxygen. That some 16, of them go to form an atom of sodium; about , an atom of barium; and , an atom of radium. On this view all the elements would be regarded as different groupings of one fundamental constituent. Of all the groupings possible, doubtless most are so unstable as never to be formed; but some are stable, or at least relatively stable, and these stabler groupings constitute the chemical elements that we know. The fundamental ingredient of which, on this view, the whole of matter is made up, is nothing more or less than electricity, in the form of an aggregate of an equal number of positive and negative electric charges. This, when established, will be a unification of matter such as has through all the ages been sought; it goes further than had been hoped, for the substratum is not an unknown and hypothetical protyle, but the familiar electric charge. Nevertheless, of course, it is no ultimate explanation. The questions remain, what then is an electric charge? Definite questions these, and doubtless some day answerable; indeed, powerful methods of attack on this position have been already contrived by Dr. Larmor and others; but they are questions of a higher order of difficulty than those which occupy us to-day, and it must remain for a future Romanes Lecturer to report progress in these directions, whenever adequate progress has in fact been made. That is the end of the first half of my lecture; and six months ago that, somewhat expanded, might have been the whole of it, because the next portion would have seemed too fanciful; but discoveries have been made, chiefly in France and in Canada,â€"some of the most striking of them within the present year,â€"which remove the treatment of the next part of my subject from the realm of fancy to the region of probability, and justify my proceeding further with some of the theoretical consequences deducible from an electric theory of matter. I referred above briefly to the origin of radiation, saying that by the method of applying a powerful magnet to a source of light, and examining the minute perturbations in the lines of the spectrum thus produced, it had been proved that the real source of radiation was an electric charge in rapid orbital motion; and I now go on to say that by careful measurement of the amount of perturbation it has been definitely proved that it is our friends the negative electrons, with a mass about one-thousandth of the smallest known atom of matter, that are responsible for the excitation of ether waves or the production of light. Larmof and others have indeed shown mathematically that whenever an electric charge is subject to acceleration, an emission of some amount of radiation is inevitable, by reason of the interaction of its electric and magnetic fields; and it is probable that there is no other source of light or radiation possible except this change in the motion of electrons. All light, and all the Hertz waves or pulses employed in wireless telegraphy, are due to electric acceleration, and the greater the rate of change of velocity the more violent is the radiation emitted. The charge may oscillate, as in a Hertz vibrator, or it may revolve, as in a source of ordinary light such as a sodium flame. In order to emit perceptible radiation by revolving, it must revolve with extreme speed in a very small orbit, so that its rate of curvature or centripetal acceleration may be considerable; for it is on the square of the value of the average acceleration that the energy of radiation depends. All this is of the nature of a definite and certain thesis; but now we are going to apply it to our hypothesis that the atom of matter is either wholly or partially composed of electrons in a state of vigorous motion among themselves. Such revolving or vibrating electrons are subject to acceleration, either radial or tangential, and must therefore to a greater or less extent necessarily emit radiation; it becomes natural to inquire whence comes the energy that is radiated away. The atom, if it lose energy, must lose what is to it an essential ingredient; and hence this inevitable radiating power of the constituents of an atom seemed to constitute a difficulty, for it suggested that an atom of matter was not really a permanent and eternal thing, but that it contained within itself the seeds of its own decay and ultimate dissipation into the separate electrons of which it was composed. The process might indeed be exceedingly slow, the radiation loss might be almost imperceptible, but, in so far as an atom is composed of revolving electrons, it is inevitable that radiation of energy must go on from it, and that this must in the long run have some perceptible degenerative result. The phenomenon of spontaneous radio-activity, discovered first by Becquerel in uranium and thorium, and greatly extended by the brilliant chemical researches of M. Curie which resulted in the discovery of radium, was at first supposed to consist in the emission of a sort of X-rays or ether pulses; and was subsequently assumed to consist chiefly in the bodily emission of electrons, which were shot off from the radio-active substance as they are from a negative electrode in a vacuum-tube, or as they are in air when ultra-violet light falls upon clean negatively charged surfaces. As a matter of fact both these modes of radiationâ€"the wave form and the corpuscular formâ€"are emitted by radio-active bodies, but they turn out to be of subordinate importance, and must be regarded as secondary or subsidiary results of the main phenomenon. The main fact of radio-activity has been shown by Professor Rutherford of Montreal, in a paper published in the month of February this very year, to consist in the flinging away with great violence of actual atoms of matter: This furious bombardment from a radio-active substance continues without intermission and apparently without sign of diminution or cessation. There is every reason to believe that a minute scrap of radium, scarcely perceptible to the eye, may go on emitting these energetic projectiles for hundreds of years. At first sight the fact that it is merely atoms of matter which are being flung off by most radio-active substances, and that ethereal and other effects are subsidiary to this emission of substance, seems to lessen the interest attaching to the phenomenon, reducing it to something of merely chemical importance, and suggesting a resemblance to scent or other volatilization from solid bodies. But Professor Rutherford, with great skill, succeeded in determining approximately the atomic weight of the utterly imperceptible amount of substance thrown off as well as its speed and found that it was not by any means the radio-active substance itself which was evaporating, but something quite different. Plainly if an elementary form of matter is found to be throwing off another substance, it becomes imperative to inquire what that substance is, and what it is that is left behind. Now the atomic weight of radium, or of thorium or uranium, or of any known strongly radio-active substance, is very high, in each case over times the atomic weight of hydrogen, whereas the atomic weight of the substance flung off appears to be more nearly of the order 1 or 2; in other words, the substance thrown off is more likely to be either hydrogen or helium than it is likely to be radium. It is just possible, as Rutherford and Soddy suggest, that the inert chemical elements are bye-products of radio-activity. Now clearly here is a fact, if fact it be, of prodigious importance. Undoubtedly the measurements require confirmation, but for myself I see no reason to doubt them, at least as regards their order of magnitude. The atomic weight of radium being say , and that of the projected portion being say 2, the residue must represent by its atomic weight the difference between the heavy atom of the original substance and that of the light atom or atoms which have been flung away: The substance left behind in the pores of the radio-active substance has been examined even more completely than the projected portion: It can be stored in gas-holders when mixed with air, for in amount it is quite imperceptible to all ordinary tests; and yet it can be passed through pipes and otherwise dealt with. It condenses not far above the temperature of liquid air, and it is itself radio-active, but in such a way that its power decays rapidly with time. Its radio-activity seems to consist likewise in throwing away part of itself and leaving yet another residue, likewise radio-active; and one

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of the residues so left seems ultimately to pitch away electrons simply instead of atoms of matter.

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John Locke (-) is a largely influential early modern philosopher of the British Empiricist type. His two areas of most significant contribution include political philosophy and epistemology.