THE CONCEPT OF MATTER AND MATERIALISM IN THE ORIGIN AND EVOLUTION OF LIFE

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Abstract

The scientific notion of matter as it developed in history cannot be isolated from its philosophical and religious connotations. It is necessary to understand that history and those connotations in order to understand what we might possibly mean today by "materialism". For instance, with Newton matter ceased to be a viable scientific concept. The philosophical stance of materialism, therefore, cannot be attributed, as is commonly held, to classical physics, but rather to a preconceived dualism that opposes matter to spirit and, if one accepts the preconception, has every good reason, on scientific grounds, to eliminate the latter.

A tentative case can be made that modern scientific research into the origins and evolution of life in the context of the evolution of the universe as a whole no longer permits that dualism. Scientific evidence shows that evolution from the Big Bang to the human brain has been a continuous process of complexification where the passage from inorganic to organic to prebiotic to biotic to intelligent does not demonstrate clear scientific demarcations. This presents many challenges for religious thought, especially as regards the human being in relationship to the evolutionary process. The challenge is best addressed by respecting the best of scientific thinking, even if that requires a fundamental critique of previous religious and philosophical tenets.

Matter for the Ionians and for Aristotle

The Greeks of fifth century Ionia, in their attempt to understand the world and themselves in it, started with three quite obvious observations: things are of many kinds and most of them can be classified, things have a beginning and many of them an end, things change. They sought to get a comprehensive explanation of these three facts. Comprehensive is the important word. How to explain everything? What they did is to assert that there is a "stuff", matter, that is shared by everything they experienced. Matter is what endured through change; matter is what was universally shared but then became specified for different types of things and different individuals of the same types. Did matter have a beginning? Did it have an end? How could this matter come to be so many different things? Were the human being, dust and water of the same matter? This notion of matter was very empirical and sensory; it was "stuff". As time went on it created more questions than answers. But the questions were probing ones.

Aristotle abstracts from this empirical "stuff" and then talks of matter in an ambiguous way which creates great problems for the future. He first talks of matter as the subject of change(s): the leaf which is green today and brown tomorrow; the man who has black hair today and white ten years from now. The leaf and the man are the "matter" of change. But then he also talks of matter when there is a change from one kind of being to another: a seed to a tree, an egg to a chicken. We can speak no more now of a change but rather of a coming to be. Is their a continuity in this coming to be? Is there a "stuff" which endures and, if so, can we detect it? Surely the chicken does not differ from the egg simply by having more "stuff". It is not the quantity of matter which makes a new being. What does? For Aristotle there appears to be a dynamic content to matter. New types of beings seem to come from it. The ambiguities increase. The rarefaction and condensation of matter become important because they explain the differences in the four fundamental types of matter: earth, air, fire and water. But how does one explain the density of matter? The atomists, of course, have the easiest approach. Density is a measure of the space between atoms. But then the difficulties mount: what is space? is there a void? We are nonetheless at a crucial point; we are beginning to speak of the amount of matter in a given space or of the "quantity of matter". We will soon see that this notion, at least in the physics of motion, will put an end to the notion of matter altogether and give rise to that of mass. And then the notion of mass will become closely allied to that of space.

In addition to the three observations of the ancient Greeks mentioned at the beginning there is the further experience to explain: matter may move. It is in the analysis of motion that further problems about matter come to light. The ancient Greeks discussed falling bodies and suggested that the speed of the fall depended upon the weight of a body and air resistance. But what did it mean for matter to have weight, to be heavy or light? It is interesting that in Aristotle's analysis of both natural and forced motions he makes no use of his concept of matter. It appears that once Aristotle had abstracted from the empirical "stuff" of the Ionians, he would not return to it and consequently would never approach the notion of a quantity of matter. For Aristotle matter became a principle of being.

This principle is referred to as "primary matter" and it is that which underlies the changes from one type of being to another: the seed to the tree, the egg to the chicken. Further analysis of this principle shows that it is completely indeterminate, cannot be named or described but has the potentiality to be "informed", i.e., to be made definite, intelligible, actual, predictable, spiritual, etc. It is no exaggeration, I think, to say that it is in this Aristotelian notion of "primary matter" that we have the origin of the sharp, and sometimes misleading, distinctions that are to arise in Western thought between material, spiritual, living, non-living, etc. It is a notion that invites a challenge. If "primary matter" is indeterminate, pure potentiality and cannot be named or described, how does it explain anything? Does it exist? What is meant by calling it a "principle"? It was the defining of such principles which became the main task of Greek physics. At a minimum we can assert that this made Greek physics into philosophy and that the birth of modern science in the 17th century was to initiate a completely new, and even contrasting, way of doing physics, separating it altogether from philosophy.

Matter at the Birth of Modern Science. Newton and His Contemporaries

From the notion of the Ionians of matter as "stuff" to the philosophical principle of the Aristoteleans, allow me to leap over the intervening centuries, which were dominated by Aristotelianism, to the 17th century. I will concentrate on the thought of Isaac Newton, while contrasting him with other scientists of his time. Ernan McMullin introduces his study of *Newton on Matter and Activity*[i] by noting that, if one considers only his major work, the *Principia*, one could assert that Newton virtually eliminated the concept of matter from physics by replacing it with the notion, "quantity of matter", which will soon become "mass". However, notes McMullin, by examining Newton's other writings and correspondence one sees that he struggled for sixty years with the notion of "matter".

Newton was primarily interested in the notions of force, of body and of the existence or not of the void. But basic to all of these was the concept of matter and he was always drawn to the neo-Platonic emphasis on matter as inert and totally passive. Newton's preoccupation here was a theological one. He would not risk having an autonomous world which did not depend on God. But if there was no seat of action in matter, where was it? How and where did change originate? Although in the *Principia* Newton claims that he is seeking only for a mathematical explanation of motion, he is actually searching, if one judges by his other writings, for the real, physical source of changes in motion. His approach is a very inductive one. Matter for him is not at all the co-principle of substance as in Aristotle. Typical of his approach is his claim that

> The laws and properties of all bodies on which experiments can be made, are the laws and properties of bodies universally.[ii]

In Rule III of the *Principia* Newton states that "to be material is to be extended, solid, mobile, to possess inertia, to attract and to be attracted by all other bodies". For the first time attraction is added to the classical list of the qualities associated with materiality and it is, of course, in analyzing attraction that Newton begins a totally new discourse on the nature of matter.

Contrary to Descartes, Newton states that while all matter is extended not all extension is matter. He is here undoubtedly alluding to the nature of space and of the void and this will lead him to a lengthy treatment of action at a distance. Contrary to his own tendencies Newton appears to make matter active since all material bodies attract and are attracted. He seeks to avoid this by seizing upon force as the principle of activity. Here again he is in contrast to Descartes who immediately went to God as the source of activity. Furthermore, Descartes delayed the development of the concept of mass by his exclusively geometrical notion of matter. For him matter and extension were equivalent and volume substitutes for mass.[iii]

Because of his desire to maintain matter as inactive there is a tension in

Newton's thinking on the relationship of matter and force. He had the insight to realize that force was only required to explain a change of motion, including going from rest to motion. But for him matter offered a resistance to motion and resistance to him was activity. This leads him to the concept of inertial force proportional to the "quantity of matter". But where is this inertial force? Leibniz with his monads clearly puts this force in matter. Newton cannot do that. His hesitation to make matter active and his struggle to deal with the notion of action at a distance are, in my opinion, correct instincts which will eventually lead to the development in physics of force fields. It is of some interest to note that in the cases of both Leibniz, who made matter active, and of Newton, who refused to do so, the motivation was theological. Leibniz thought it would be demeaning of God to require that he always be acting in matter and Newton felt that God would easily be excluded altogether if he were not the immediate source of activity in matter.

In light of these diverse views as to activity in matter we might ask: Was gravity essential to matter? For Newton the answer was clearly negative because he could not accept the notion of essential. To him essence was an ontological principle of being inherited from the Aristoteleans and his was an inductive and empirical notion of matter. For him gravity was universal, but it was not essential. For Newton matter continued to be a substratum for all empirical properties, including attraction.

We now summarize the most important elements of Newton's physics with respect to matter. He rejected the Aristotelian notion of prime matter as an ontological principle of all created being in favor of a return to the Ionian notion of matter as a substratum for the empirical qualities which he studied by induction. He struggled to eliminate the notion of matter being active but, in so doing, he could not ultimately explain his notion of the "force of inertia" and the attractive force of all matter. In proposing the notion of "quantity of matter" he leads the way to the concept of mass. From Newton on matter is eliminated from the discourse of physics and is replaced by mass. As has been noted by others[iv] it is paradoxical that the rise of materialism as a philosophy in the 17th and 18th centuries is attributed to birth of modern science, when in reality matter as a workable concept had been eliminated from scientific discourse. Matter, in the new physics, is not measurable.

Matter in Physics after Newton

Newton typifies the struggles with the notion of matter in physics at the time of the birth of modern science. To complete this picture somewhat, let us now examine a bit of the aftermath of Newton. In his *Theory of Natural Philosophy* (1763) Roger Boscovich introduces the notion of point centers of force, instead of extended solid corpuscles. These point centers have inertia and a single force acting at them is supposed to explain all of the qualities of matter. There is thus a tendency in Boscovich to the reification of force, to making it the "stuff" of the Ionians and the substratum of Newton. This tendency is furthered, although not intentionally, by Euler in his mathematics on the mechanics of fluid media. Euler opposed the reification of forces and he believed in an aether. But in his *Principia motus fluidorum* (1761) he presented an idealized mathematical model for the transmission of action in a continuous medium. This mathematization soon led others to develop the notion of force fields whereby the relationship of bodies to one another is characterized by the specification of forces in a space-time coordinate system. Was a medium required for the exercise of these forces? What was a "field"? Faraday specified these questions by formulating empirical criteria for claiming that a particular field involved real processes in intervening space.[v] By his criteria optical, electrical and magnetic fields are real, whereas gravity is action at a distance. Except for gravity this seemed to require an aether but all attempts to find such an aether failed. Maxwell's unification of light, electricity and magnetism in a single mathematical formulation still left the question of an aether unresolved. Hertz led the movement towards the inevitable defeat of aether theories with his statement: "Maxwell's theory is Maxwell's system of equations" and with his reproach of those who tried to cloth the mathematical equations with the "gay garment" of a physical counterpart.[vi] The reality is the mathematical formulation of the reality. The advent of relativity theory, of quantum field theory, of quantum cosmology, etc. will only further complicate the discussion of the nature of matter as to action at a distance.

The mathematization of physics that we have just been addressing will continue through the classical revolution in physics of the 17th and 18th centuries and will become, in a different way as we shall see, an essential ingredient of the new physics of the 20th century. As usual in scientific revolutions, what was happening only came to full realization after it had happened. A three-layered conception of the universe, only partially inherited from the Platonic-Pythagorean tradition, came to be accepted implicitly, and only slowly did it come to consciousness. There was the layer of the true mathematics, the mathematical structures of which the world is truly made. Then there was the second layer, the mathematics of we humans, structures which were in a Platonic sense only the shadows of the first layer. Finally there were at the third layer the images in concrete reality of the true mathematical structures which we humans attempted to understand with a our shadow mathematics. However, there is a subtle development, described well by Michael Heller,[vii] in which at the second layer mathematics is not only the language or the interpretative tool of physics, but it becomes also the "stuff" of the ideal world of physics. For the present this "stuff" remained under the control of empirical verification i.e., the third layer. The images in concrete reality, remained the test of how true the human mathematical structures were.

The rise of quantum mechanics and of relativity theory at the beginning of this century soon weakened the connection between the second and third layers described above and, in fact, reemphasized the connection between the second and first layers. The images in concrete reality made very little, if any, sense as a test of mathematical "stuff" of the ideal world of physics. There are no natural images or representations which correspond to Hilbert spaces, the mathematical "stuff" of quantum theory. And while general relativity has passed all of the experiments yet made to test its empirical predictions there are no adequate images or representations which correspond to motions at relativistic velocities or under very large gravitational forces. In its "purest" form the physics of both the sub-quantum world and the world "beyond-relativity" is strictly mathematical in the tradition of Plato and Pythagoras and has little to do with any sensory component.

There is another area in which the new physics has advanced our understanding of the nature of matter. The studies of the dynamics of non-linear systems has given birth to the fields of chaos theory and complexity. This represents, in some sense, a return from quantum physics to the world of macroscopic physics and it is, in another limited sense, a vindication of Aristotle's view that the world of the senses is too rich to be limited to or comprehended by mathematics. There are really two parts of this: deterministic chaos arising from classical mechanics and non-linear systems in thermodynamics. The immense variety of forms, shapes and structures which we find in both the inorganic and organic world challenges any theory that they could have come forth from some deterministic set of laws of physics. And yet, using the mathematical analysis of non-linear systems and the laws of physics, we can come to understand the structural design for changes, but we cannot predict the result because we cannot know what result small perturbations, accumulated in a non-linear way, will produce. Thus while we can analyze mathematically and, in that sense, understand the structure of such dynamical systems, we cannot predict the outcome because of the accumulative effect of non-linear perturbations. In the end the world of the senses has a richness which defies ultimate mathematical analysis.

From Physics to the Biosciences

This leads us rather naturally from the world of physics to that of biology and chemistry, of biophysics and biochemistry. The very fact that we have such developed fields of dual denomination is an indication of the direction in which the discourse is now directed. The well established scientific evidence of the complexification of matter in the evolutionary process leads me to suggest that we have returned once again to the notion of matter as a substratum, but now that notion is much enriched both by the mathematics of non-linear systems and by our knowledge of biochemistry. What now dominates our thinking, as it did for physics in the case of the historical development towards field theories, is the concept of relationship.

No part of the universe can be understood except in its dynamical and evolutionary relationship to all other parts of the universe. The specification of matter (an electron, a quark, DNA, the human brain, etc.) is attained by its relationship to and interaction with all other parts and with the whole. The best of scientific knowledge tells us that all of the diverse objects in nature have had a common origin and have shared in and come from a common evolutionary process.

An initial eruption of energy soon gave birth to the first matter in the universe in the form of quarks which in turn formed the first sub-atomic particles until finally the simplest of all atoms, hydrogen, was formed. As the universe continued to expand

and cool, matter continued to organize itself in ever more complex structures: molecules, dust, galaxies, stars, proto-organic substances, vegetation, mammals. This evolution in an ever expanding, universe evolving towards ever more complex organization of material required also a diversification of the original energy of the universe into various forces: nuclear, electromagnetic and gravitational.

Over the centuries the debate has raged over the relative place of chance and determinism in this evolutionary process. While the laws, for example, of physics as we know them are quite deterministic, - given a cause the effect follows inevitably - we know today of many systems which are non-deterministic, or in the language of mathematics, non-linear systems. These are systems, whether physical, chemical or biological, where, although the causes or concatenation of causes are all defined and known, we cannot predict the final effect, because an undetermined and undeterminable series of fluctuations intervenes between cause and effect. This non-linearity becomes more dominant as evolution proceeds to ever more complex systems.

Pure chance is not in itself a satisfactory explanation for this increasing complexification. But we might still ask to what extent chance played a role. The philosophical inclinations of Albert Einstein are not well understood. In his physics, however, he was clearly deterministic. In the debate over the meaning of quantum mechanical indeterminism he claimed that God does not play with dice. Recently an eminent biochemist, Christian de Duve, has replied: Yes He does, because He is sure to win.[viii] In attempting to frame his conclusion in the context of Einstein's statement, what de Duve is actually claiming is that intrinsic to the universe there is an interplay of determinism, chance and opportunity. His response to Einstein was to state that it is in the very nature of the universe that intelligent life inevitably come to be, although a long and complicated process involving laws, chance happenings and propitious opportunities was required.[ix]

Dualism Challenged by Continuity in Evolution

Throughout the historical development of the notion of matter there has been a dominant tendency towards dualism in the origins and evolution of the universe. I have suggested above that this tendency was strongly supported by the Aristotelian notion of prime matter as a principle of indeterminacy and potentiality for change, even to new kinds of beings. A further contribution to this dualistic tendency comes from religious considerations. We have seen an example of this in Newton and Descartes and in their contemporaries. Descartes in particular required two levels of being: matter and spirit, and matter was completely inactive, motion having been communicated to it by God at creation. This tendency endures to our day. In order to preserve the primacy of God, of the spiritual, of the supernatural some have found it necessary to insert discrete moments in the continuous evolutionary process which we have described above. According to this position, organic could not arise from inorganic, life could not come from non-life, the human intelligence and spirit could not come from matter. God must have intervened at these critical phases in evolution. Such positions appear to contradict the most recent scientific evidence available which sees a continuity in the natural processes which lead to the complexification of matter in the universe.

This dualistic tendency is usually resolved in one of two extreme ways: materialism or divine intervention. Put in its most simple expression crass materialism will not allow that complexification in the evolutionary process can lead to new kinds of beings. All beings, however, complex, are reducible to their material parts. At the other extreme, is the position that essentially new beings, and especially the human being, require a direct intervention by God in the evolutionary process. Materialism, as I have described it, is, I believe, essentially refuted as an inadequate view of what is meant today by material, that all beings are related to all other beings in the universe in their common origin and common evolution towards more complex systems. The need for an interventionist God is essentially refuted by the scientifically well established continuity in the evolutionary process and its explicability in a scientific analysis which need not be a threat to informed religious thought.

I would like to give one explicit example of what I mean. Recently on 22 October 1996 John Paul II issued a brief message on evolution[x] to the members of the Pontifical Academy of Sciences during their Plenary Session. He introduced his message by asking: "How do the conclusions reached by the various scientific disciplines coincide with those contained in the message of revelation?". While the encyclical of Pope Pius XII in 1950, *Humani Generis*, considered the doctrine of evolution a serious hypothesis, worthy of investigation and in-depth study equal to that of the opposing hypothesis, John Paul II states in his message:

> Today almost half a century after the publication of the encyclical [*Humani Generis*], new knowledge has led to the recognition that the theory of evolution is no longer a mere hypothesis.[xi]

The sentences which follow this statement indicate that the "new knowledge" which the Pope refers to is for the most part scientific knowledge. He had, in fact, just stated that "the exegete and the theologian must keep informed about the results achieved by the natural sciences". The crux of the message is the discussion of the opposing theories of evolutionism and creationism as to the origins of the human person. In the traditional manner of Papal statements the main content of the teaching of previous Popes on the matter at hand is reevaluated. And so the teaching of Pius XII in *Humani Generis* that, although it may be true that the human body takes its origins from pre-existent living matter, the spiritual soul is immediately created by God. And so, is everything resolved by embracing evolutionism as to the body and creationism as to the soul? Note that the word "soul" does not reappear in the remainder of the dialogue. Rather the message moves to speak of "spirit" and "the spiritual".

If we consider the revealed, religious truth about the human being, then we have an "ontological leap", an "ontological discontinuity" in the evolutionary chain at the emergence of the human being. Is this not irreconcilable, wonders the Pope, with the continuity in the evolutionary chain seen by science? An attempt to resolve this critical issue is given by stating that:

> The moment of transition to the spiritual cannot be the object of this kind of [scientific] observation, which nevertheless can discover at the experimental level a series of very valuable signs indicating what is specific to the human being.

The suggestion is being made, it appears, that the "ontological discontinuity" may be explained by an epistemological discontinuity. Is this adequate or must the search continue? Is a creationist theory required to explain the origins of the spiritual dimension of the human being. Are we forced by revealed, religious truth to accept a dualistic view of the origins of the human person, evolutionist with respect to the material dimension, creationist with respect to the spiritual dimension. The message, I believe, when it speaks in the last paragraphs about the God of life, gives strong indications that the dialogue is still open with respect to these questions.

I would like to use the inspiration of those closing paragraphs to suggest that reflections upon the God's continuous creation may help to advance the dialogue with respect to the dualistic dilemma mentioned above. We might say that God creates through the process of evolution and that creation is continuous. Since there can ultimately be no contradiction between true science and revealed, religious truths, this continuous creation is best understood in terms of the best scientific understanding of the emergence of the human being which I think is given in the following summary statement by the eminent evolutionary chemist, Christian de Duve:

> . . . evolution, though dependent on chance events, proceeds under a number of inner and outer constraints that compel it to move in the direction of greater complexity if circumstances permit. Had these circumstances been different, evolution might have followed a different course in time. It might have produced organisms different from those we know, perhaps even thinking beings different than humans.[xii]

But does the contingency involved in the emergence of the human being contradict religious truth? Not, it appears to me, if theologians can develop a more profound understanding of God's continuous creation. God in his infinite freedom continuously creates a world which reflects that freedom at all levels of the evolutionary process to greater and greater complexity. God lets the world be what it will be in its continuous evolution. He does not intervene, but rather allows, participates, loves. Is such thinking adequate to preserve the special character attributed by religious thought to the emergence of spirit, while avoiding a crude creationism? Only a protracted dialogue will tell.

Notes

i. McMullin, E.: *Newton on Matter and Activity* , University of Notre Dame Press, Notre Dame, 1978.

ii. Cohen, I.: Hypotheses in Newton's Philosophy, *Physics* 8 (1966) 163-184.

iii. Jammer, M.: *Concepts of Mass in Classical and Modern Physics*, Harvard University Press, Cambridge, Massachusetts, 1961, pp. 58-61.

iv. McMullin, E..: op. cit in Note 1, page 1 and Heller, M., Adventures of the Concept of Mass and Matter, *Philosophy in Science* 3 (1988) 15-35.

v. Faraday, *M.: Experimental Researches in Chemistry and Physics*, London, 1859.

vi. Hertz states this in the Introduction to his *Untersuchungen über die Ausbreitung der elektrischen Kraft*, Leipzig, 1892; translated by Jones, D.E. as *Electric Waves*, London, 1893.

vii. Heller, *M.: The New Physics and a New Theology*, Vatican Observatory Publications, Vatican City, 1996; distributed by the University of Notre Dame Press, Notre Dame, Indiana, pp. 36-39.

viii. de Duve, C..: Life as a Cosmic Imperative, *The Origin and Early Evolution of Life,* Pontificia Academia Scientiarum, Vatican City, 1997; Commentarii, Vol. IV, No.3, p. 320.

ix. de Duve, *C.: Vital Dust: Life as a Cosmic Imperative,* Basic Books, New York, 1995.

x. The original message in French was published in *L'Osservatore Romano* for 23 October 1996 and an English translation in the Weekly English Edition of *L'Osservatore Romano* for 30 October 1996. The French text is now also published in *The Origin and Evolution of Life,* Pontificia Academia Scientiarum, Vatican City, 1997; Commentarii, Vol. IV, No. 3, pp. 15-20.

xi. The English translation of this sentence, published in the Weekly Edition of *L'Osservatore Romano* for 30 October 1996, is incorrect when it says: " ... the recognition of more than one hypothesis ...".

xii. de Duve, C..: op. cit. in Note 9, page 320.