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Dialectical Materialism and Developments in Contemporary Science

INTRODUCTION

Today we are more than a century and a half away from the origins of what we would recognize as dialectical materialism. In the era when this philosophy was being formulated, science, in many disciplines was passing through a phase of incremental progress. Biology was different, as Darwin's work created something of an upheaval, but in other disciplines it seemed to be an era of evolutionary progress rather than radical transformation. All of this changed in the first half of the twentieth century, a period marked by the tumult of both the socialist revolution and the radical advance of the sciences. After the many transformations that have taken place since, in both the social-political world and the human knowledge of the natural world, it is clearly of value to dialectical materialists to renew their understanding of a dialectics of nature. This is a demanding undertaking and it would need the collective effort of many to fulfill such a mandate even partially.

This note will attempt only a modest survey of some aspects of dialectical materialism in relation to contemporary science. This note has four sections that deal with the following issues.

a) A survey of some highlights of contemporary science in relation to some key concerns of dialectical materialism.

b) A brief survey of the response of bourgeois philosophy of science to the advance of 20th century science.

c) Some brief notes with regard to dialectical materialism and science in the Soviet Union

d) Some observations on the current challenges to the dialectical materialist viewpoint in relation to science, particularly with regard to dialectics.

I . SOME HIGHLIGHTS OF 20TH CENTURY SCIENCE

We will begin by recalling some of the most significant advances of the science of the 20th century. We will do so in a manner that specifically highlights some of the traditional concerns of the dialectical materialist viewpoint. There are undoubtedly subtle aspects of these advances that need to be discussed, but we will return to some illustrative examples of these later in the notes.

We remind the reader that by the term "traditional concerns" we mean the following:

The primacy of mind over matter.

The view that matter is essentially objective reality, that has an existence independent of human perception or human existence. Matter and energy are interconvertible.

The human brain is the most organised and the highest form of matter.

Matter is always in motion. There is no motion without matter.

All objects and processes are interconnected and interdependent.

The world must be understood not as a complex of ready-made objects and things but as a complex of processes, in which all objects and things are continuously undergoing changes and development.

The term development encompasses both motion and growth.

The basic laws of the development of matter are:

a) the unity and struggle of opposites leading to development

b) quantitative changes lead to qualitative changes

c) the law of the negation of the negation.

We also recall that the stand and viewpoint of Marxists in relation to the overall advance of science is perhaps best captured in Engels' speech at the graveside of Marx: "But this was not even half the man. Science was for Marx a historically dynamic, revolutionary force. However great the joy with which he welcomed a new discovery in some theoretical science whose practical application perhaps it was as yet quite impossible to envisage, he experienced quite another kind of joy when the discovery involved immediate revolutionary changes in industry, and in historical development in general."

We emphasize once again that the rest of this section is not intended to mean that the advance of science has been one of unqualified success and not without false starts, wrong perceptions and the pursuit of incorrect lines of research, resulting in the continual appearance of numerous contradictions in the scientific view of the natural world. But in viewing the advance of the scientific knowledge over the last century, we must emphasize the continued assertion of the "instinctively dialectical materialist" character of science as revealed in its practice.

To ignore this aspect of science in favour of an outright skepticism with regard to the developments of contemporary science would be a non-dialectical viewpoint. On the one hand, such skepticism presupposes that when bourgeois society is transcended, science under socialism will constitute an outright rejection of much of contemporary science and not a dialectical negation. It also denies the reality that science is in essence not merely a contemplative activity, a view that bourgeois philosophies constantly revert to, but that scientific knowledge is acquired through both theoretical reflection as well as the conscious intervention of human beings in Nature.

SOME SUMMARY OBSERVATIONS

In summary we may begin by noting the following in relation to dialectical materialism and the developments of 20th century science:

- The materialist view of a mind-independent objective reality that the activity of science seeks to explore and understand has increasingly become part of the overt and explicit view of science, strikingly exemplified in the physicists' view of the structure of the atom and its substructures.
- The view of space and time as attributes of matter in motion has been remarkably deepened by the theories of relativity.

• Objective reality is both structured and differentiated, with new levels of the organization of matter requiring new laws and is recognized as such by contemporary science in an explicit manner.

• In the case of physical matter, qualitative transitions arising from quantitative changes has become part of the standard understanding of science.

• Science has discovered the interconnected nature of objective reality in ever newer forms. The universal nature of the laws of science discovered on Earth has been established in practice in their ability to explain and occasionally predict phenomena in other regions of the universe.

• The development of quantum mechanics brought to the fore an objective contradiction in physical matter in the form of wave-particle duality. This is in contrast to the nature of contradictions in physical matter that had been studied before where the appearance of contradictions and their resolution were simultaneous (For instance in the case of planetary motion, where the attractive gravitational force of the Sun is balanced by the outward force due to the circular motion of the planet).

• The varied advances in biology irrevocably indicate the unity of all forms of living matter.

• The discovery of the "elementary" constituents of living matter and the discovery of the common set of processes at the molecular level that these constituents obey, provides the foundation for this unified view of living matter.

• Alongside these discoveries, one of the great achievements of 20th century biology in particular has been the integration of evolutionary biology with genetics. Subsequently these discoveries have also set the stage for a surge of advance in the study of the development of living matter, all the way from the its origins in physical and chemical processes in non-living matter to the evolution of the human species. Development here, it must be emphasized, is understood in the sense of both growth and motion.

• Modern evolutionary biology acknowledges the need for qualitative different explanations at the level of macroevolution, including speciation, that however do not contradict the fundamental view of adaptation and natural selection.

• The notion that all matter is in a constant state of evolution is now considered applicable to non-living and living matter in all its forms and at all levels. Implicitly, even in the case of physical matter the laws of motion governing motion due to various fundamental forces are themselves recognized to be capable of quantitative change and more generally, possibly, qualitative change.

• That the specific capabilities of the brain and the nervous system, ranging over a wide variety of functions, have a material basis in physical, chemical and biological structures is now well-established, by a variety of methods.

We now turn to a more detailed account of the basis for these observations in the development of 20th century science.

(a) Space and time as attributes of matter in motion

The science of mechanics underwent a radical transformation in two distinct ways in the twentieth century. The first transformation began with the theories of relativity, first the special theory of relativity and subsequently the general theory of relativity. Both these radically deepened the understanding that space and time are the attributes of matter in motion. In the special theory of relativity matter and energy were shown to be convertible, breaking down the traditional division between the two that had dominated science so far. Time was shown to be an intrinsic aspect of the motion of matter and not a (eternal) background in which matter was embedded (and certainly not an a priori conception, independent of matter or indeed objective reality). Space and time were shown to be on the same footing; it was space-time that was the attribute of matter in motion and not two independent attributes known as space and time.

The general theory of relativity took matters even farther, showing that not only uniform motion, but even accelerated motion was an intrinsic property of matter. Accelerated motion was identified with gravitation. Of course since Newton, gravitation is known to be an attribute of physical matter that does not depend on the qualitative features of its different forms. The general theory of relativity also initiated the theory of the evolution of physical matter, in a certain sense almost as though by stealth. The general theory of relativity naturally led to the description of the evolution of the entire universe, where the term universe refers to all of space and time and the matter contained inside it. (NB It is worth emphasizing that Newtonian mechanics did not describe a purely static universe, but an universe with only uniform or periodic motion. The great merit of Newton's laws of motion, as J.D. Bernal has emphasized, is the break from the Aristotelean view of motion as the overcoming of friction. Newton's first law of motion proclaims motion (even if only uniform motion) as a fundamental attribute of matter).

Thus the understanding of dialectical materialism that there is no motion without matter is considerably deepened by the development of the special and general theory of relativity.

(b) The discovery of wave-particle duality and the development of quantum mechanics

The second radical departure from the traditional view of mechanics was the development of the mechanics of the micro-world, known as quantum mechanics. The discovery of the atom and its structure forced this development since without the new mechanics these new discoveries were not explainable or understandable and often led to irreconcilable contradictions with the existing notions of mechanics. Experiments showed that the hydrogen atom, for instance, consisted of a positively charged proton as the nucleus with an electron orbiting it. From the viewpoint of classical mechanics and electromagnetism however, such an atom could not be stable since the electron must spiral into the positively charged nucleus and annihilate it.

This contradiction was resolved by quantum mechanics. The term "quantum" in quantum mechanics referred to the fact that quite frequently, in the micro-world of atoms, electrons and their constituents, various attributes of matter such as energy, etc. took only discrete values. Thus, in the case of the hydrogen atom, the electron orbiting the nucleus, did not have a continuous range of energy but had only specific values of energy. This explained why the electron did not spiral in to annihilate the nucleus (which involves a continuous decrease of the energy of the electron).

While this property that the various physical attributes of matter (such as energy, momentum, etc.) could take only discrete values in many situations was forced by various experimental phenomena, it nevertheless needed the development of the new mechanics to understand why this should be so.

A critical ingredient to the development of the new mechanics was the discovery that all "particles" could be considered to be both waves and particles. This discovery began with light itself. While light had been considered to have a wave-like nature for more than 250 years, it was found to behave like a particle in some physical situations such as the photo-electric effect. In such situations the wave-like nature of light was not manifest at all. Subsequently, beginning with the electron, it was established that this dual character of wave and particle was true for all particles. In classical mechanics, the wave and particle nature of objects are mutually exclusive.

The importance of this discovery cannot be overemphasized, as it was the first discovery of an explicit and manifest contradiction in the physical world. This "wave-particle duality" and the related notion of complementarity (as it was referred to by one of the architects of the new mechanics, Niels Bohr), referring to the fact that when the wave nature was manifest the particle nature was not and vice versa, became one of the essential features of the new mechanics. The objective contradiction of wave-particle duality can be one-sidedly resolved, with a purely particle-like or purely wave-like description, but this can be done only by prescribing very different properties to particles and waves, properties that are different from those that were commonly recognized from the era before quantum mechanics.

The new mechanics had very puzzling new features; comparatively speaking the special and general theory of relativity caused much less theoretical confusion and were rapidly considered to be well established. One of these was the "uncertainty principle" (due to Heisenberg, another architect of the new mechanics). This principle asserts (in its most well-known form) that both the momentum and the position of a particle could not be specified (even theoretically) with arbitrary precision. This uncertainty arose since the new mechanics included an objective probability (as opposed to probability in the sense of a lack of precise knowledge) as part of the description of nature. Physical matter in general did not have precise values of its properties, such as position, momentum or energy, but had only a probability distribution over a range of possible values.

Such an objective probability in the description of the physical attributes of matter raised the obvious question of how when actual measurements are carried out on electrons and such particles in experiments, they provide only a particular number as the value of position or momentum for every single particle. Underlying this question (known in the scientific literature as the measurement problem) was a deep puzzle, namely the relationship between the everyday world of Newtonian mechanics that is accessible to perception and the mechanics of particles such as electrons that were described by quantum mechanics. It is only recently that a viable answer to this puzzle has begun to emerge, though the question today continues to be one of active research. One of the major reasons for this has been that many experiments that were conceived of earlier to test various fundamental aspects of quantum mechanics but could not be carried out due to technological limitations (and hence were referred to as "thought experiments") can now be realised through the advances of modern technology in the hands of very innovative experimenters.

The discovery of quantum mechanics and its development gave rise to considerable philosophical debate as well. Many scientists and philosophers thought that quantum mechanics had abolished the distinction between subject and object, since it appeared that the experimenter could choose whether to make the wave nature or the particle nature of matter manifest. It also appeared that measurement always irretrievably interfered with the intrinsic properties of the object and thus always partially determined the outcome. Clearly such questions were a challenge to the notion of a mind-independent objective reality. However contemporary scientific research on the fundamental interpretation of quantum mechanics, that continues to be a very active research area, has pushed back these anti-materialist notions with concrete experimental investigations. Today measurements can be made without irretrievably changing the property under investigation. Such developments have marked a retreat in the anti-materialist interpretations of quantum mechanics that even many scientists had espoused in an earlier era.

The development of quantum mechanics is one of the most fascinating stories of intense activity by a community of scientists in the modern era that resulted in a complete revolution in our understanding of an entire branch of science. Despite the considerable weight of its theoretical puzzles, both in the past and even today, quantum mechanics in the sense of an operational set of rules works remarkably well to great accuracy. The advance of modern physics in the 20^{th} century is inseparable from the use of quantum mechanics.

(c) The physics and chemistry of materials

One of the outstanding consequences of the new quantum mechanics, was that it provided the empirical rules of chemistry a firm basis in a quantum theory on the nature of chemical bonds, that bound the atoms of different elements to form molecules. One may argue that the development of quantum mechanics provided for the science of chemistry what Newton's theory of gravity provided for the science of the motion of planetary bodies, namely the clarification of the basis of hitherto empirical rules (such as Kepler's laws of planetary motion) on the basis of an underlying law of nature. The clarification of the underlying basis of the notion of chemical valency and the subsequent development of these ideas on the basis of the quantum nature of the chemical bond have led to significant inputs into the growth of the science of materials, based on their chemical properties.

The modern science of materials may be said to begin with the discovery of quantum mechanics. Even such well-known phenomena as the conduction of heat, the conduction of electricity, the magnetic properties of materials received their first consistent theoretical explanations with the advent of quantum mechanics. The modern science of materials is one of the great developments of twentieth century science, with an enormous number of applications. Among these applications are of course all the developments in material science that underlie the advances of modern information technology.

Even outside information technologies, many devices that we regard as commonplace are the consequences or outcome of quantum mechanics. One of the well-known examples of this is the invention and the later applications of lasers.

Another aspect of the science of materials that has registered great advance is the understanding of the various transitions between different phases of matter. From the primitive understanding of the transitions such as melting and evaporation or condensation and freezing, contemporary physics has developed an enormously sophisticated machinery for understanding the transitions between qualitative ly different "phases" of matter that arise from the quantitative change of some attribute (such attributes need not be just temperature as in the case of melting or evaporation). This understanding is applied not just at the level of ordinary matter such as water or solids, etc. but is applied even to the large collections of elementary particles or atoms or just collections of protons and neutrons. Such considerations are important in the study of stellar objects in astrophysics.

In the development of science today, the study of qualitative changes that arise from quantitative changes is virtually commonplace in the scientific understanding.

(d) Structure of matter

The exploration of the structure of matter in the 20th century has utilised the discoveries of special and general relativity and quantum mechanics in a fundamental way.

One of the first significant discoveries of the 20th century was the fact that matter that is perceived to be solid (and so apparently continuous and infinitely divisible) is actually made up of discrete atoms. These atoms are for the most part empty space as it were, with the bulk of the mass of the atoms concentrated at the points corresponding to the nuclei of the atoms.

With regard to the structure of matter, the discovery of the atom (following a few years after the discovery of radioactivity) set off a line of scientific advance that has proceeded to extraordinary lengths. The progression of discoveries: atom —> atomic structure —> nuclear structure (including protons and neutrons) —> structure of the nuclear particles such as the proton and neutron — > quarks (the constituents of the proton and the neutron) was achieved over a period of just over half a century. Simultaneously, the view of atoms or the atoms of particular elements as unchanging entities was decisively overthrown, opening the way further to an evolutionary view of physical matter that was to follow.

At the same time, the long-standing dualism of matter and forces has been overcome with the understanding that what was conventionally referred to as the action of forces is now understood as the exchange of particles (there is a certain subtlety involved here which we will refer to shortly). Thus electromagnetic forces are due to the exchange of photons. Apart from the electromagnetic force and the gravitational force (known by the end of the 19^{th} century) two new forces were discovered, the weak and strong nuclear forces. It is now understood that two of these forces are now unified (the weak nuclear force and the electromagnetic) at higher energies and there are indications that eventually all forces should perhaps be thought of as unified. Thus from the unity of different forms of motion known in the 19^{th} century, science has put the understanding of the unity of forces on the agenda. The diversity of forces that are seen in the contemporary period of the history of the universe are the consequence of the "freezing" out of various forces at different periods of time. Obviously these developments have raised the notion of the unity of different forms of the motion of matter to a new and higher level.

A very interesting aspect of the notion of quarks is that an individual quark is not a directly observable entity. This is because the forces that bind quarks to make protons and neutrons are such that it requires an infinite amount of energy to pull two quarks apart. Nevertheless for contemporary physics, quarks are real objects, whose properties are inferred from complex experiments. The anti-materialist notions that once made even scientists doubt the existence of atoms or electrons no longer carry the same influence among scientists of the contemporary era.

(e) The connection of the macro-world with the micro-world and the development of cosmology as a science

Together with the headlong rush in the uncovering of successive levels of the structure of matter, there arose new branches of science that dealt with the overlap between these successive levels. But more interestingly, the developments of the mechanics of the micro-world turned out to be significant not only to understand the structure of the material world around us, but also of profound significance in understanding the nature of the large-scale objects in the Universe beyond the boundaries of the earth.

Thus the fusion of hydrogen atoms to form helium, the basic physical process underlying the hydrogen bomb, turned out to be the basic process that governed the production of the energy of stars, and the radiation that they emitted. Subsequent to this discovery the physics of the micro-world has increasingly become connected to the physics of the macro-world, in a new dialectic of the large and the small. The new particles and forces discovered in the exploration of the sub-structure of matter turn out to have profound significance for the behaviour of not only stars but other cosmic objects such as supernovas , neutron stars, and so on. However such stellar objects in general are constituted by these particles in qualitatively new forms of organization.

One of the fruits of this line of research is the current, fairly well-established evolutionary theory of the elements of the periodic table, which describes how these elements were created from much more elementary forms of matter in the process of the formation of the current observable universe. We have already indicated that the general theory of relativity laid the foundations of a theory of evolution of physical matter. In contemporary physics, the theory of the evolution of physical matter is the subject of the modern science of cosmology (the term is now used in contemporary philosophy in a distinct, though slightly related, way), that studies at the same time, both the current universe and the manner in which it came into being. Indeed, particularly in the last decade, based on observations through a number of satellites, cosmology has registered some of the most interesting advances.

The science of cosmology and the physics of elementary particles are considered now as closely related disciplines. The idea that the properties of elementary particles in fact reveal the conditions of the Universe at very early times has now been absorbed into the language of contemporary physics (and indeed routinely appears in press releases by the particle physics laboratories such as the European Centre for Nuclear Research (CERN) in Geneva).

Many of these results are based on the big bang "model" of the formation of the universe. Scientists today largely accept that this "origin" does not therefore a moment of creation (with all its uncomfortable theological sounding implications of this term) and that this model breaks down in describing what appears to be the "origin" of the universe and space and time. At the heart of resolving this breakdown lies one of the major theoretical contradictions that confronts contemporary physics, namely the contradictions between the general theory of relativity and quantum mechanics. This is an area of much study and research in contemporary physics.

Overall the developments in the science of cosmology and related disciplines has put an end to any illusion that even physical matter in the universe is not in a state of motion and development. The physical, non-living world, as much as the living world of biology to which we will soon turn, is equally subject to evolution and change.

These descriptions are not meant to suggest that all aspects of these theories are equally well understood and that the entirety of what I have described above all have the same status in terms of the extent of their scientific validity. Nor do I wish to suggest that the viewpoint from which these developments have been regarded by the majority of scientists and thinkers has been that of dialectical materialism. As the complex history of science and philosophy in the Soviet Union shows, understanding these developments from the viewpoint of dialectical materialism has not been an easy task either. But what I do wish to emphasise is that, prima facie, the great developments of the physics of the twentieth century have provided a tremendous opportunity to sharpen and make more profound the dialectical materialist viewpoint.

(f) The development of modern biology and the understanding of evolution

The second great arena of advance of modern science has been that of biology. Despite the impressive successes of the Darwinian theory of evolution, the clarification of the actual mechanism whereby the individual variations amongst the members of a species arose remained unclear until the development of genetics, the discovery of DNA and the subsequent elaboration of its role in the process of reproduction and the mechanism of heredity. However the deep connection between genetics and evolution was already present in what is known as the "modern synthesis," due to Dobzhansky, Fisher, Haldane and others, prior to the discovery of DNA. The modern synthesis is by itself an outstanding achievement as the rediscovery of Mendelian genetics had set of a wave of debate whether genetics is indeed consistent with evolutionary theory. The discovery of the structure of DNA and the subsequent developments in the field of molecular biology set off what may truly be termed a second Darwinian revolution. Modern evolutionary biology has been an area of rapid advance, starting from a deepening understanding of the fundamental processes involving DNA and other forms of nucleic acids (RNA, and other related variants) to the study of bio-diversity and large ecosystems.

It is clear that evolution is no longer a theory but an accepted fact. Its most obvious and everyday (so to speak) illustration is the development of antibiotic resistance in various bacteria in the field of medicine and pesticide and herbicide resistance in agriculture. In both cases, evolution of resistant species by adaptation is directly the cause of antibiotic or pesticide resistance.

With the original discovery of DNA the molecular basis of one part of adaptation (adaptation is a two-step process with the random mutations in reproduction being one step and natural selection by the environment the next one) was made clear. However, it has also become evident that there are other means for this first step of adaptation. One prominent example is that of symbiogenesis, whereby one species absorbs the genes of another species. Symbiogenesis is a specific case of the more general phenomenon of horizontal gene transfer, whereby organisms of one species may acquire part of the genome of another organism. Such horizontal gene transfer is fairly ubiquitous in nature, indicating that genetically modified organisms are not a violation of the natural order (as many tend to believe in the era of Bt brinjal and Bt cotton), though the resulting man-made version also has very little predictability and desirable properties have to be created essentially by trial and error. Thus the understanding of the molecular basis of evolution has led to greater depth in the understanding of the process of adaptation, though the exact significance of horizontal gene transfer to the process of evolution may remain a matter of scientific research.

Another significant contribution was offered by the introduction of the notion of punctuated equilibrium. In this view, originally due to Gould and Eldridge, evolution is not a story of continual gradual growth but includes of phases of relatively rapid advance and change between long periods of much slower development when species may stabilise. It must be emphasized though that rapid here is only in relation to geological time and the transition here is also over thousands of generations. This view has appeared to gain qualified acceptance today by an increasing number of scientists in evolutionary biology. However while the theory of punctuated equilibrium differs from the original view of uniform gradualism of similar tempo over long periods, it does not invalidate the general picture of adaptation as the driving force of selection. It is also relevant to note that even in the study of the physical evolution of the Earth, due to considerations relating to climate change, today more attention is being focused on periods of relatively rapid advance compared to long periods where relatively little change occurred. It is clear that there have been periods in the Earth's history when for instance polar ice sheets have melted at a very rapid rate compared to other periods when such rapid transition did not occur.

It is accepted today that evolution is not an account of uniform progress, though it is also true that evolution is capable of generating forms and organisms of greater complexity. The most complex form is of course the development of the human species with its specific property of consciousness. It is interesting to note that this does not imply that animal genomes are progressively longer and more complex genomes than that of plants. The various distinctive features of the ability of animal species to respond to stresses, for instance, are encoded by shorter genome sequences, while response to stress in organisms such as plants, require longer genome sequences.

It is important to note that one of the consequences of the development of evolutionary biology, to which scientists such as Mayr and Gould have frequently drawn attention, was the recognition of the problem of macroevolution, particularly speciation, as a problem at a qualitatively new level, that was not reducible to the genetic mechanisms that underlay the process of adaptation and evolution of single species, though they are in conformity with the latter. A qualitatively new understanding was required and these have been developed over time.

The fundamental understanding of the processes and mechanisms of living organisms has been continuously and rapidly expanding in other ways also. Even before the discovery of DNA and other nucleic acids, the chemical processes of the living organisms continued to be increasingly better understood. But the DNA revolution has contributed to the understanding of biological processes at the fundamental cellular level. There has been continuous development of our knowledge of how the basic information for the subsequent development of the entire organism is encoded in the DNA and how this finds expression in the concrete environment in which living things are reproduced and grow. It is difficult to describe the stream of outcomes that has come out of the revolution in molecular biology, especially when we realize that we have reached the era of stem cell therapy and cloning. It is clear that the understanding of molecular level processes at the level of the cell has greatly contributed to our understanding of the nature of various diseases that appeared earlier to be entirely mysterious in their origin. At the same time controversy continues over whether the disciplines of modern biology and modern medicine have tended to overemphasize the molecular level understanding without adequately accounting for the behaviour of entire sub-systems within the body or the body as a whole.

To a far greater degree than physics, these developments in biology, especially in the era of genetics, have been the source of much ideological dispute, both in the public arena and in academic debate.

One of the consequences of evolution is that it completely overturned the idea of a fixed classification of the objects of the natural world. We have already noted the idea of the notion of the evolution of the natural world. But the world of physics at the time of Darwin still dealt with unchanging entities. However evolution decisively established the changing character of species, the fundamental building blocks of the observable biological world. Particularly after the modern synthesis and the discovery of DNA there has been considerable debate over the unit of natural selection. At the same time, the very concept of species itself has also often been called into question. It is interesting that the response of some biologists, particularly Ernst Mayr, to these debate has been instinctively dialectical. In his decisive rejection of a reductionist view based on pure genetics, Mayr has defended the view that it is the full organism that is the unit of selection. In the case of the definition of the concept of species, Mayr has defended the relevance of the biological species concept despite its transitory character.

Modern biology has also deepened the understanding of agriculture to a significant degree and modern agricultural production is increasingly closely related to fundamental scientific advance.

Marx and Engels accorded the work of Darwin, particularly the publication of the Origin of the Species, an enthusiastic reception. Engels' view and critique of Darwin's work, his appreciation of Darwin's achievement (" the proof of our ideas in the natural sciences of our time" - Marx) and yet his firm critique of the concept of the struggle for existence that Darwin introduced (unfortunately borrowed almost certainly from the work Herbert Spencer) are a brilliant anticipation of the modern view of adaptation[1]. Despite this, especially in the era after the discovery of DNA, many dialectical materialists have tended to a fairly skeptical view of evolutionary biology. We will have occasion to make further remarks on this later on.

However in concluding this section we re-emphasise that, at the beginning of the 21st century, it is clear that the entire range of developments in biology are both best captured and exemplified by the dialectics of nature in a remarkable way, well beyond what even the pioneers of the dialectical materialist viewpoint may have envisoned.

(g) The origin of life

Following on evolution the next logical step clearly lies in a theory of the evolution of living matter from non-living matter. The first steps in this were taken by Oparin and Haldane. This field despite its undoubtedly slow progress has become an established area of scientific research. In the most current versions of the theory, the link between the more complex forms of nucleic acids and the earlier chemical soup that must have existed is believed to be a soup of RNAs, whose reproduction would be driven by what are known scientifically as auto-catalytic reactions.

(h) The Brain and Consciousness

Special mention may also be made of the further developments in the understanding of the functioning of the brain. While many fundamental and even basic questions remain unsolved, nevertheless the operational understanding of some aspects of the brain's functioning has advanced considerably. Today, the brain can be made to directly control artificial limbs, for instance, thus bridging in practice the gap between thought and action at the simple mechanical level. At the heart of the advances in our knowledge of the brain lies another revolution, this one related to the development of new and advanced instrumentation. Biology in general and medicine in particular have been the beneficiaries of this progress to a significant degree. From the humble X-ray to the advanced scanning techniques of today, this progress has made it possible to examine at least the elementary aspects of the functioning of the living brain. Among the most frequently cited of these in recent times is the scanning technique known as Positron Emission Tomography (PET) that gives a view of which parts of the brain are activated during the execution of particular activities or thought processes, usually in response to some external stimulus (not necessarily physical).

The idea that the material functioning of the brain through its physical, chemical and biological processes is the basis of consciousness has never been as strong as it is today. Clinical psychiatry provides further evidence of this, as the chemical basis of various clinical psychiatric disorders are understood, and based on which new drugs are developed. Schizophrenia, bipolar disorder and depression are some ailments whose chemical connections are well known and are being studied for some time. The point here is the understanding of the objective basis of disorders relating to aspects of the brain's functioning that are characteristically described in non-physical terms (one may say even "subjective" in a certain sense) such as mood, behaviour, etc.

(h) Modern experimental science and technology

Modern science would not be what it is of course without the development of new technologies that have assisted experimental science. These technologies range from information technologies to developments in satellites or to new materials. Using these technologies for experimental science has transformed experimental science as the work of a few in a single laboratory to vast enterprises that can involve a few hundred scientists on a single "experiment" as well as requiring the effort of hundreds of technicians, engineers and other workers in the background. Contemporary experimental science therefore is collective knowledge production in a sense that was not known earlier.

(i) Interdisciplinary sciences & the study of the environment

It would be erroneous to argue that contemporary science has only further fragmented disciplines and produced an increasing number of specializations that function within increasingly narrow boundaries. Interdisciplinary sciences in various forms have arisen for the study of specific aspects of reality such as the atmospheres of planets, the climate of the Earth, the functioning of the brain, and so on. The mosaic of various sciences continues to present a picture of both increasing specialization and the reconnection of various sub-disciplines to form new areas of scientific study.

Special mention should be made of the general area of environmental sciences, where the intersection of methods and results from biology, chemistry and physics is quite common. There is also increasing recognition in this area of the link between technology and the study of the environment. Environmental concerns have also brought to the fore the link between the social sciences and the impact of human activity on the environment.

(j) Mathematics and computational sciences

The development of mathematics in the 20th century has a dual aspect. On the one hand the 20th century marks the era of a further formalization of this science, particularly in its foundational aspect, reflected in the highly abstract, ahistorical form in which it is conventionally presented and discussed. Such formalization greatly assisted in taking the scattered and "empirical" observations of earlier eras and sharpening and deepening them into entire sub-disciplines of the subject. At the same time, new branches of mathematics continue to be developed based on the needs and demands of other scientific disciplines that also increasingly take recourse to the tools of mathematics. Some of the most significant advances of mathematics in the latter half of the 20th century have been driven for instance by developments in the arena of theoretical physics.

Interestingly, the increasing formalization of mathematics brought to the fore the objective contradictions inherent in mathematics itself, most famously in the paradoxes of set theory and results such as Godel's theorem. This theorem that established the limits of any logical system, also asserts the impossibility of a complete and consistent logical formulation of all of mathematics within a limited set of axioms. Godel himself insisted that within mathematics, his theorem embodied a "real" contradiction.

The development of computers and its influence on mathematics merits special mention. Computer science has increasingly demanded the use of the most advanced mathematical techniques, such as the use of number theory for encryption. At the same time, computer science and the techniques of electronic computation and representation (as in the use of images, etc.) have developed new branches of mathematics or have given new meaning to old problems in mathematics, that had been set aside for long periods.

II. SOME OBSERVATIONS ON SCIENCE AND PHILOSOPHY IN THE 20TH CENTURY

(a) Some mainstream philosophical views on science

It is one of the outstanding features of contemporary bourgeois philosophical thought that despite the remarkable advance of science in the 20th century it has fallen back on philosophical positions that are deeply skeptical of science and the ability of science to eventually provide an increasingly reliable view of the natural world. In doing so however, philosophy of science also walls itself off as a separate discipline, preoccupied with its own self-generated concerns while its influence on the way science is actually done recedes continually.

This contradiction between the development of science under capitalism and the inability of bourgeios philosophical thought to capture the essence of this advance is clearly rooted in one of the striking features of contemporary science. Frontier science irrevocably left behind in many respects its links with the world of everyday experience and phenomena observable by unaided (or with the assistance of simple instruments) human observation. This is perhaps one of the key distinguishing features of the science of the 20th century that separates it from the science of the previous eras. It is unsurprising then, that bourgeois philosophy, that for the most part swings between empiricism (the view that knowledge is acquired primarily from sense data) and rationalism (the view that knowledge is primarily a product of pure thought) without being able to overcome this duality, finds contemporary science a particularly intractable problem.

From the viewpoint of dialectical materialism, broadly speaking all philosophical positions with regard to the understanding of the natural world may be classified in terms of their sharply divided positions on some key questions. The first divide is obviously the one between those who accept the mind-independent nature of the natural world as opposed to those who deny the existence of any mind-independent natural world. The latter position, traditionally identified with idealism, is not a major force in the contemporary philosophy of science. However there is a qualified form of this view that is still common that we shall describe shortly.

However even among those who accept the existence of a mind-independent nature, there is a sharp division among those who insist that our knowledge is confined to we can perceive or sense and those who insist that mind-independent objects or processes exist even if we cannot perceive or sense them. In a variant of this divide the emphasis is placed not on existence but on knowability. In this sense, the former position can be restated in the form that we can know only about things that can be perceived or sensed, whereas we will never about the intrinsic character of things. This is the classical view due to Kant and is the view traditionally identified, broadly speaking, with the philosophical position that is referred to as positivism. The opposing view would assert that we can infer the existence of things that we do not directly perceive or sense and know about its properties.

The heyday of positivism was in the first half of the twentieth century when logical positivism sought to reduce scientific theories to consistent and unique logical systems constructed out of a set of proposition based on measurement, or empirical evidence, and another set of propositions based on logical deduction. The activity of science thus lay in verifying the correctness of the statements that could be generated by logical arguments based on these two sets of propositions. In the well-known variant due to Karl Popper, verifiability was to be replaced by falsifiability, meaning that it was only necessary to find one logical consequence of the theory that was not true in experiment for the theory to break down. It is widely acknowledged today that entire program ended in utter failure, an admission made in the 1970s by the philosopher A. J. Ayer who was himself one of its foremost proponents.

Another divide that has emerged more commonly in contemporary philosophy of science arises not from considerations of the existence per se of the objective world or its knowability, but on whether the order that science perceives in the natural world is imposed by the human mind or is inherent in nature. This modern variant of positivism asserts that while the human mind does not cause nature to exist, all of the scientific notions of order, structure, the different kinds of objects and their properties are functions of the human mind. A typical view of this kind is due to the philosopher Hilary Putnam and is referred to as internal realism. It is evident that this view is a qualified idealism, that while acknowledging a bare objective reality, devoid of any structure, attributes all the content of this objective world to the mind.

This view has been bolstered by the argument that a very large number (if not actually infinite) number of scientific theories can fit the available experimental data, the so-called thesis of under-determination of scientific theories. Thus while the scientific community may decide on considerations such as aesthetics, symmetry, etc. for a particular scientific theory, there is no reason that this theory, with all its structure, actually describes how nature is.

A third major contribution in the same vein has been the work of the philosopher/sociologist Thomas Kuhn on theory change. Coming after the radical transformations of the first half of the twentieth century, Kuhn's work focused on the nature of the radical breaks in the scientific understanding of the natural world. Kuhn's view of this transformation was founded in a positivist view that fully accepted the Kantian dictum that science provided knowledge of only the part of the objective world that we saw and perceived. In Kuhn's view science in normal periods gradually solved a number of puzzles within a given set of rules (or paradigms). However at some point when it encountered a new puzzle or puzzles that could not be solved within the old rules it made a radical shift to a new set of rules. In Kuhn's view, science thus saw a new world as it were, with scientific thinking undergoing a radical mental shift (a gestalt-switch as it is described, borrowing a term from psychology). Thus even to Kuhn the order in the natural world was an order imposed by the human mind.

Another version of an anti-positivist philosophical position, that is nevertheless deeply skeptical of science has arisen from other sources. Originating in a tradition of philosophy of science in France and Germany, it has eventually merged with the broad philosophical trend known as post-modernism. From this philosophical viewpoint science is an arch exemplar of the values of the Enlightenment such as rationality, truth, and progress etc. to which post-modernism takes in general a skeptical stance.

Taken together these versions of anti-positivism are characterised by some of the following features.

The first is a radical relativism towards concepts such as rationality and truth, that is then extended to science. Relativism is the attitude that while justifiably noting that even philosophical conceptions change over time proceeds to the conclusion that these conceptions have no substantial meaning at all. This radical relativism in the case of science has joined the currents of relativism in anthropology and sociology in rejecting any idea of progress or advance of scientific knowledge and asserting that all views of the natural world, whatever their origin, are equally valid.

The second feature is the assertion that the content of scientific theories are determined by considerations that have little or no bearing on the objective validity of different theories based on their theoretical content and their subsequent experimental verification. The third aspect of these views is their utter methodological confusion. These views draw for their justification on detailed studies of the history or the sociology of science, using characteristically scientific methods, leaving us with the strange spectacle of social science being used to argue that there is no consistent natural science. The fourth aspect is that these views deny that the criticism that they make of science is as valid for their own version of social science. To be consistent their skeptical view of science has no more intrinsic justification (by their own argument) than the opposing view that science produces genuine knowledge.

Despite their high pretensions to having decisively struggled against positivism, these tendencies in fact share considerable common ground with the latter-day versions of positivism. They are firmly empiricist in character (in the sense that what really counts is only perceptions and sense-data), and they do not acknowledge the reality of the objective world beyond the world that we actually see.

Another common feature of these theories is their hostility to Marxist philosophy. In the more popular expositions of these views, the tendency is to label Marxism by virtue of its scientific attitude as another version of positivism. More generally, in the regular social scientific literature, there are a large number of works that typically identify science with positivism and on that basis advocate an uniformly skeptical view of science. Such literature, despite its high academic credentials, is often tantamount to sheer misrepresentation of science and/or Marxism.

(b) Scientific Realism

Scientists themselves, with some exceptions among biologists and even more rarely among physicists, have largely tended to shun the development of any serious philosophical view of their discipline. This tendency has had a dual effect, on the one hand leading to a crudely philosophical view of their discipline (Stephen Hawking's latest popular science book and its pronouncements on religion are a good example) but on the other also pushing them to ignore philosophical prejudice and test various alternatives in their theories and experiments. There have however been some brilliant exceptions, though rare, such as the serious philosophical interventions from the physicist Steven Weinberg and the biologist Ernst Mayr.

Apart from dialectical materialists, particularly in the Soviet Union when it existed, and other materialists, the only stream in academic philosophy that has consistently tried to understand how and why science works has been the philosophical tendency known as scientific realism. Scientific realism is distinct from materialism in the sense that it does not articulate the view that consciousness and ideas are secondary to matter. However in many ways it may be said to incline towards a materialist position.

Scientific realism holds that science does produce an increasingly accurate view of a mind-independent natural world, even though its results at any given historical moment are subject to correction with the development of science. Scientific realism also holds that the objects and mechanisms that scientific theories introduce are intended to be real provided that they can eventually be justified and proven to be correct. The correctness of scientific theories arises from their ability to explain various phenomena and/or justification from observation and experiment. One of the most appealing aspects of the scientific realist view is its overarching argument that the ultimate justification of science lies in the fact that science works in practice. Science enables human beings to actively intervene in Nature both in the form of experiment and in the form of practical technological activity. This is referred to as the "no-miracles" argument, meaning that the success of science would have to be treated as a miracle, if we did not accept that science actually described the workings of a mind-independent world.

Scientific realism however is a minority trend in the world of the philosophy of science. In many ways the most satisfying (for the dialectical materialist that is) work among scientific realists continues to be the early work of the British philosopher, Roy Bhaskar. Though in his later work, beginning with his obscure writings on dialectics, he has eventually relapsed into utter obscurantism, his initial work was closely inspired by Marxist philosophy.

In general, however, one of the major weaknesses of scientific realists has been their inability to deal with radical scientific change in an adequate way. Most scientific realists in reacting to Kuhn's anti-realist view have reacted by emphasizing continuity and downplaying the element of change. This is most glaringly evident in scientific realist discussions of quantum mechanics, which tend to be either inadequate (as in the work of Christopher Norris) or are not dealt with in detail at all.

(c) Non-Aristotlean logic and dialectics

Even if very briefly, mention must be made of developments in logic that are of interest to dialectical materialists. The traditional view of Aristotlean logic as the examplar of all work on logic has long been on the decline. Several developments including the study of non-European philosphies, especially from India, developments in computer science and the advance of logic itself have driven this trend. Within this trend there is a small but active tradition of research that particularly investigates logical systems that explicitly allow for contradictions. Particular mention may be made of the work of the philosopher Graham Priest and of the work of the philosophers Routley and Meyer in a slightly earlier period. The work of Priest is notable for attempting in particular a detailed critique of the positivist view of motion, as exemplified for instance by the very influential work of Russell, and sketching a possible defence of the Hegelian view of motion. Nevertheless this work still falls short of dialectical materialism in its weakness in absorbing fully the import of the Hegelian (and Marxist) view of negation.

(d) What is missing in contemporary philosophy of science?

The dialectical materialist reader of these notes would have undoubtedly noticed that two elements are strikingly absent from the account of bourgeois philosophy of science so far.

The first is the absence of a viewpoint on biology as a central aspect of the philosophy of science. Under the heading of the philosophy of science what is usually presented is the philosophical implications drawn from physics. There is to be sure a sub-discipline of the philosophy of science, referred to as the philosophy of biology, but that is limited to accounts of philosophical questions within biology as a separate discipline.

The second even more glaring absence is the role of practice in formulating a philosophy of science. Philosophy of science has at best considered experiment, though even here the number of those who have studied the issue in its own right have been very limited. But even in these views, the dominant theme is that of an active kind of empiricism (as opposed to the passive view of perception), where the claim is that scientific theories are to be judged on the basis of their "empirical adequacy". Mainstream philosophy continually avoids recognition of even a limited role of practice. It always seeks a standard of judgement of science that stands above both theory and practice.

III. DIALECTICAL MATERIALISM AND THE CONTEMPORARY ADVANCE OF SCIENCE

(a) The experience of the Soviet Union

One of the major losses from the fall of the Soviet state is undoubtedly the loss of access to the achievements of the Soviet Union in theoretical Marxism. A great deal of work was undertaken in the Soviet Union on the philosophical understanding of science, spread over a large number of institutions and large numbers of people. This work was both at the general philosophical level as well as involving the study of the philosophical questions arising from the practice and theory of specific disciplines and sub-disciplines. This work, in notable contrast to the rest of the world, actively involved both philosophers and scientists, both of whom addressed the philosophical views at hand in various disciplines.

Much of the literature generated in this area was obviously in the Russian language and is available only to those knowledgeable in the language. English language sources in this work were limited, often only popular and not technical. Academic literature on this subject in the West has been dominated by anti-Soviet writing from Sovietologists with very limited writing that was outrightly interested in the philosophical issues. The most notable source is of course the work of Loren Graham, mainly "Science and Philosophy in the Soviet Union," and later works. This work is critical, but on the whole fair and reasonable, and even sympathetic in many respects, though the author is not a professional philosopher. Detailed work by sympathetic philosophers are very rare and Marxists in other countries, notably in the West seemed to have written little on philosophy in the Soviet Union. It must be mentioned that the study of the dialectics of nature took place in the background of the enormous development of science in the Soviet Union, that had a significant number of achievements to its credit.

The study of the dialectics of nature in the Soviet Union had some notable successes, especially where the use of dialectical materialism explicitly influenced the formulation of new scientific theories.

Among these undoubtedly the most significant are the achievements of Soviet psychology and the formulation of the problem of the origin of life, with its first tentative scientific account. The other outstanding achievement undoubtedly was the critique of the dominant positivist understanding of the development of quantum mechanics. The Soviet critique of the so-called Copenhagen Interpretation (as the dominant interpretation due to Bohr and Heisenberg was known, the term itself being a Marxist coinage) undoubtedly played a pioneering role in the history of physics.

Overall the study of the dialectics of nature undoubtedly played an important critical role in many scientific disciplines, resisting the positivist or even idealist interpretations that marked the response to new scientific developments in the capitalist world. Soviet scientists for instance were critically aware of the theological flavour of the assumptions of the original version of the big-bang model of the universe. Undoubtedly Soviet science developed a wide-ranging critique of the many regressive aspects of the interpretations of science that were current in the capitalist world.

However the practice of dialectics in relation to contemporary science also had some significant negative features. In several instances, those resisting new developments in science would appeal to dialectics or materialism in their arguments, characterising particular interpretations as idealist or mechanical. At the same time, it was easy to brand some new development as idealist or positivist based solely on their origin outside the Soviet Union in the West. In particular periods in Soviet history, the violation of socialist democracy added a particularly nasty tone to such debates.

Dialectical materialists cannot ignore the lessons of the unfortunate episode of Lysenkoism. In significant mitigation of the gravity of the error, it must be emphasised that Lysenkoism arose when the connection between genetics and evolution was just being formulated and genetics in the West was often dominated by racist views such as eugenics. Nevertheless Lysenko clearly represented the failure of ideology "dictating" to science, setting aside concrete scientific theory and practice. Lysenkoism was also clearly bolstered by the cult of personality and violations of socialist democracy that was pervasive in many aspects of life in the Soviet Union in the era of Stalin's leadership. The violation of socialist democracy was clearly pernicious in its impact on many aspects of ideological life (though perhaps we should also be careful not to exaggerate such impacts and their lasting character).

Lysenkoism however was only the extreme version of a more general problem. In the USSR, the debates on the dialectics of nature often did not seek a resolution in the concrete advance of science itself, except on rare occasions. A fine exception was for instance the work of Fock on the general theory of relativity, where he put his philosophical conceptions to the test through concrete research in general relativity (though his attempt was largely deemed outside the Soviet Union to be valuable only as critique). This major weakness is visible for example for instance in the Soviet debate on the interpretation of quantum mechanics. One of the major advances in this debate in the West was due to the work of the British physicist John Bell, who developed methods to test different conceptions of quantum mechanics by suitable experiments. This development most recently has also been aided by sheer technological development that made it possible to actually conduct experiments that were earlier thought to be possible only as "thought experiments". It is notable that Soviet physics does not appear to have contributed significantly to the work on "Bell's theorem" (as Bell's work is known) after it was formulated.

Alongside this weakness, was the complementary one of not accepting that some theoretical or interpretational issues could eventually be settled only through the historical development of concrete science and not just through philosophical debate. It was entirely possible that contradictions in thought, even in selecting the right dialectical interpretation, reflected objective contradictions or insufficient scientific knowledge and that the resolution of these contradictions in theory had to be sought in further scientific development over a historical period. In practice of course this happened on many occasions as philosophical debates exhausted themselves without fruitful results. But this aspect of the resolution of scientific debates within dialectics does not find any clear articulation.

We must leave this subject here as these notes are not the place for an extended evaluation of dialectical materialist philosophy in the Soviet Union. In parallel with the debates in the philosophy of science there were extended debates over philosophical issues per se, covering issues such as the nature of motion (Zeno's paradox and so on) or the question of the relationship of formal logic to dialectical logic. Both of these were intensely debated in the USSR without (as far as I am personally aware) any definitive resolution. Clearly we still need to set out at least a descriptive account of the main trends in philosophical debate in the Soviet Union in some major areas of interest to the dialectical materialist viewpoint.

(b) Dialectical materialism outside the Soviet Union and Science

We will merely note here that outside the Soviet Union the outstanding achievements of dialectical materialism that directly contributed to science included the work of the British biologists who were close to Marxist philosophy, the contribution of Japanese physicists such as Taketani and Sakata to the understanding of the dialectics of nature (this was directly responsible for developing the idea of quarks) and the contribution of Marxists such as Bohm and Vigier to the critique of the positivist view of quantum mechanics. There were also scientists who were closely sympathetic to Marxism, such as Gould or Mayr, who significantly contributed to significant advances in biology.

Another significant achievement was undoubtedly the development of the history of science, beyond a purely so-called "internalist" account in the world of J. D. Bernal and Joseph Needham, that were directly related to their affinity to Marxist philosophy. However a dialectics of nature in the West has clearly also suffered significantly in the confusions raised by various versions of "Western Marxism."

IV. SOME ISSUES IN DIALECTICAL MATERIALISM TODAY

What is the situation in relation to dialectical materialism and contemporary science today?

Accepting for the moment a separation, purely as a matter of convenience, between the notions of materialism and dialectics, it is clear that the materialist conception of the world has never been stronger. With respect to the materialist viewpoint , some of the most fundamental and long-standing philosophical speculations regarding the structure of matter have been spectacularly substantiated.

And many of the later developments have gone well beyond even the most far-reaching philosophical speculations that had preceded them.

At the same time the ideological importance of re-affirming a materialist conception of the natural and social world has never been stronger. Especially in the context of the various versions of what is referred to as "post-positivist" philosophy, that has particularly seized contemporary social science in their view of the natural world, reaffirming materialism in the light of contemporary science remains very much on the agenda. The attack on a materialist view of science is in reality very often a proxy war against a materialist view of the social world. Particularly in the developing world, with large residues of pre-capitalist ideologies and modes of thinking, "post-positivist" philosophies end up providing support to obscurantism and backward-looking ideological agendas. In such circumstances, when combating issues such as astrology education in Indian universities, one may even ally with the positivists against such obscurantism.

In some tendencies within Marxist philosophy, there has also been a trend to de-emphasize the word materialism in the combination, to talk of it as a metaphysical appendage that could be ignored whereas the thrust lies with the term dialectics. As is evident from a range of anti-materialist philosophies, dialectics without materialism opens the door to relativism. Without providing an objective basis for change, dialectics would degenerate to change and transformation of a purely subjective or voluntary kind, and thus there is no way to decide why the transformation that one is describing is positive or truthful or progressive etc. This is really why Kuhn's celebrated "paradigm shift," though it identifies the radical nature of scientific change, reduces it to a subjective transformation driven by anomalies or unsolvables puzzles in experience.

However the real issue remains a correct understanding of a materialist dialectics[2]. Historically, in most presentations of dialectics it has become standard to present in the form of some general characteristics of motion and the three laws of dialectics. The three laws are usually stated as the mutual interpenetration of opposites, qualitative transformation as the result of quantitative transformations and the law of the negation of the negation. This mode of presentation has been extensively criticised even among Marxists. While clearly such simplified formulations have played an important pedagogical role in the wide dissemination of Marxist philosophy, they are insufficient for the development of Marxism as a science. Regrettably though they also dominated the extensive Soviet popularisation of dialectical materialism. However it would not be correct to infer that this simplified version constituted all of Soviet discussions on dialectics. There is enough evidence to show that serious philosophical debate in the USSR went much farther.

From the perspective of this simplified formulation of dialectics it is clear that the viewpoint of dialectical materialism has in no way been weakened by the advance of contemporary science. We have already remarked on the explicit manner in which science recognizes the transformation of quantity to quality.

The law of the negation of the negation appears to perform two functions in relation to the dialectics of Nature. One function of this law is to assert the arrow of time. Nature always moves forward with change. This is of course not to be simplistically interpreted as progress, as Engels astutely noted in his remarks on evolution. But with specific reference to the biological world the law of the negation of the negation has clearly stronger meaning in the process of both simple reproduction and growth. The second function is in relation to the advance of scientific knowledge. Science not only moves forward with new explanations and theories but it also explains why the old theory appeared to be true, to the extent that it explained any aspect of objective reality. An excellent example is the Ptolemaic understanding of the solar system where the Earth was at the centre. With Galileo, Kepler and Newton, came the heliocentric view of the solar system. But with the explanation for planetary motion by gravitational forces and the subsequent development of mechanics, it became clear that one could equally well describe the motion of the Solar system with the Earth at the centre. In modern language, the equations of mechanics could equally well describe planetary motion accurately, even if the "frame of reference" was that of a stationary Earth. This is something of course Ptolemy could never do, since without moving to a heliocentric view the discovery of the laws of gravitation would have been impossible.

With regard to the first law, of the interpenetration of opposites, what becomes clear from 20th century science is the contrast between biology and physics. In the latter the contradictions that lead to motion are certainly much harder to locate. In general it seems that the contradictions in physical processes appear simultaneously with their resolution as in the case of planetary motion or in the case of uniform motion. Explicit objective contradictions manifest themselves more slowly over a historical period. We may note that the wave-particle duality of quantum mechanics became evident only over four hundred years of the development of physics, beginning with the wave theory of light (Newton had a particle like theory that was proved wrong), followed by the discovery of the particle like nature of light in the photoelectric effect and finally the contradictory particle-wave character of all matter in quantum mechanics. Its relation to the motion of the physical world is still an unclear issue in some respects. In contrast, the basic mechanism of selection once uncovered, already presents the fundamental contradiction driving evolution, namely the dialectic of the individual and the general.

The historian Hobsbawm once remarked that even the originally rather roughly formulated notions of historical materialism came as a radical new perspective in the study of history. One may argue that this equally applies to the dialectics of nature. But as in the case of historical materialism, one may ask how a dialectics of nature could evolve further to a deeper and sharper understanding. Such a self-reflexive understanding (meaning an understanding of itself and its own nature) we must emphasize is unique to dialectical materialism. Non-dialectical philosophies do not and cannot consider their own evolution and advance in understanding the natural and social world.

In particular the categories of dialectical materialism (by categories we mean the terms such as matter, mind-independent objective reality, quantity and quality, cause and effect, etc) may remain the same but it is their specific meaning that would be further developed or transformed. Some bourgeois philosophers consider it to be an explicit weakness of dialectical materialism that its philosophical categories appear so tied to science. On the other hand, from the perspective of dialectical materialism, while the philosophical categories may remain the same, it is their content and meaning that is enriched by the development of the productive forces as well as the successive transformations of the relations of production. Indeed, as Engels has remarked, what distinguishes ancient materialism from contemporary materialism is precisely the fact that the content and interconnections of various categories in the former were often speculative and "fantastic" and it is precisely these that are substituted by a modern understanding. It is in this sense that we may speak of the deepening of our understanding of materialism in the light of the developments of contemporary science.

The fact that understanding how the categories of dialectical materialism are enriched in meaning and content is by no means a trivial issue, is illustrated by the record of philosophical debate within Marxist philosophy in the Soviet Union and particularly in regard to the philosophical interpretation of developments in contemporary science. It is evident that this task would be even harder in a society that is still burdened by pre-capitalist ideologies and notions that arise from the endurance of a variety of social structures related to pre-capitalist modes of production.

In the first section it is precisely this goal that we have also sought to pursue from examining the record of science in the 20th century. Whether in the success of the theories of relativity or in the debates on the interpretation of quantum mechanics we have indicated how our understanding of the category of matter and the nature of the motion of matter has been advanced.

The second critical aspect of the advance of our understanding of dialectical materialism is related particularly to the aspect of dialectics. E.M.S. Namboodiripad, drew attention to the importance of dialectics in his review of the work of Debiprasad Chattopadhyaya on Lenin, where he emphasized the importance of understanding why Lenin turned to the study of Hegel, after he had written *Materialism and Empirio-Criticism*. Two important summary statements on dialectics from Lenin's *Philosophical Notebooks* (Vol. 38 of his Collected Works), make it clear what EMS was drawing attention to. The two passages are one titled "Summary of Hegel's Dialectics" and the other titled "On the Question of Dialectics" (See reference at the end).

In the second passage Lenin begins by noting that "the splitting of a single whole and the cognition of its contradictory parts is the essence (one of the "essentials", one of the principal, if not the principal, characteristics or features) of dialectics." The import of this statement is evident from all the developments of science. In the 20th century, it is clear that much of the progress of science lies in the execution of this first part, "the splitting of a single whole" to an extraordinary degree. It would be profoundly incorrect to view the advance of this aspect of science simply as reductionism. Reductionism arises elsewhere in not appreciating the process of development and qualitatively new laws at different levels. Lenin's observation is also a warning against the celebration of undifferentiated unity (often referred to as holism) as dialectics. Dialectics precisely differs from holism in this moment of the splitting of a single whole and the cognition of its contradictory parts.

The second point to make with regard to this statement is the fact that the difficulty lies precisely in the next step, "in the cognition of its contradictory parts". It is here that contemporary science, even at its best, is in something of a quandary with a one-sided thrust that privileges one or the other side. This perhaps was not a problem in the era of classical physics as the appearance of the contradiction and its simultaneous resolution could be conceived of as simply equilibrium. However in the case of wave-particle duality the contradiction was not of this kind. One-sided apparent resolutions of a contradiction invariably move the contradiction elsewhere. To think of a quantum particle purely as a particle for instance, forces one to ascribe an entirely different notion of trajectories in quantum theory. Or if one thought of it as a wave, we would have many non-standard properties for the wave.

The "cognition of its contradictory parts", which is the essential dialectical element, imposes itself as a more pressing necessity precisely where motion is rapid and immediate. On the scale of the evolution of human society, that is the most rapid scale of evolution, the cognition of the contradictory parts thrusts itself forward in the most easily recognizable form in the elements of antagonistic relations of production. At the other end of the scale, where motion is the least rapid, in the physical world, it is there that contradiction between the parts of the whole are the least imposing. Thus it is unsurprising that the unconscious philosophical attitude that accompanies the investigation of the physical world is so attached to the notions of a harmonious world, equilibrium and uniform motion rather than motion through the development of contradictions. Motion in the biological world falls in between these two extremes in the scales of motion that we see. These differences also determine the sense in which dialectics is readily applicable in varying degrees across the range of the sciences, from the social world to ultimately the physical world. It is natural in this sense that dialectics appears at first glance as a metaphysical, or worse an ideological imposition, in understanding the physical world whereas for the social world dialectics appears as a natural aspect of its conceptualisation.

It is not uncommon to find intellectuals who are pleased to proclaim themselves as historical materialists when it comes to understanding the social world, but yet are somehow embarrassed by the notion of a dialectics of nature. In another variant the dialectics of nature is thought of as a purely subjective dialectics, where it is our concepts and theories that evolve dialectically in the description of a Nature that is unchanging. Lenin underlines however the connection between a subjective dialectics and the dialectics of Nature. In "On the Question of Dialectics" he points out, "Thus in any proposition we can (and must) disclose as in a "nucleus" ("cell") the germs of all the elements of dialectics, and thereby show that dialectics is a property of all human knowledge in general. And natural science shows us (and here again it must be demonstrated in any simple instance) objective nature with the same qualities, the transformation of the individual into the universal, of the contingent into the necessary, transitions, modulations, and the reciprocal connection of opposites."

Why is the "cognition of its contradictory parts" critical to our understanding? Precisely because development is a consequence of the "struggle" of the contradictory parts. Obviously contemporary science does not use this overtly dialectical language, but even from the viewpoint of dialectical materialism, little of the development of contemporary science has been reworked and systematically understood from a dialectical viewpoint. Even in the bulk of Soviet literature, the problems are posed in the technical language of science with a dialectical materialist commentary (as in this note itself!!).

This transcription of contemporary science from the dialectical viewpoint is not merely a question of language. In comparing Lenin's exposition of the theory of knowledge in Materialism and Empirio-Criticism to his remarks in the Philosophical Notebooks and in 'On the Significance of Dialectics," we find a significant new emphasis. Dialectics, Lenin underlines, is the theory of knowledge of materialism.

Commenting on the significance of Capital, Lenin writes: If Marx did not leave behind him a "Logic" (with a capital letter), he did leave the logic of Capital, and this ought to be utilised to the full in this question. In Capital, Marx applied to a single science logic, dialectics and the theory of knowledge of materialism [three words are not needed: it is one and the same thing] which has taken everything valuable in Hegel and developed it further." And again: "Dialectics is theory of knowledge of Marxism. This is the "aspect" of the matter (it is not "an aspect" but the essence of the matter) to which Plekhanov, not to speak of other Marxists, paid no attention'." One of the fine commentaries on the meaning of these remarks is Evald Ilyenkov's "Dialectical Logic." One discipline where dialectical logic in this Leninist sense was sought to be applied was in psychology in the work of Vygotsky. For the most part though we still lack any serious study of individual sciences in this advanced Marxist-Leninist understanding. Grasping the import of Lenin's exhortation that dialectics is the theory of knowledge of materialism is clearly one of the challenges before contemporary Marxism, though it is not entirely clear how this program is to be carried out.

In the history of human thought, from among the many philosophies that have survived into the present, dialectical materialism remains one of the most fascinating philosophical enterprises that has been initiated. Even while it has drawn on the many achievements of the past in philosophy, in the new synthesis of these elements in an unique fashion , it remains a world-view that is still in its youth in the realm of philosophy. Its most striking successes have been in the understanding that it has provided of the social world, despite all the setbacks and difficulties of the immediate present. If it is develop its full liberatory potential it cannot do so without absorbing the outcomes of the advance of science that constitutes one of the most potent achievements of human society in its historical evolution.

REFERENCES

I. V. I. Lenin : Summary of Dialectics, Collected Works, Volume 38, pp 220-22

II. V. I. Lenin: On the Question of Dialectics, Collected Works, Volume 38, pp 357-361.

NOTES

1 We provide here the full relevant quotation from Engels' Dialectics of Nature: "Darwin's

mistake lies precisely in lumping together in natural selection or the survival of the fittest two absolutely separate things:

1. Selection by the pressure of over-population, where perhaps the strongest survive in the first place, but can also be the weakest in many respects.

2. Selection by greater capacity of adaptation to altered circumstances, where the survivors are better suited to these *circumstances*, but where this adaptation as a whole can mean regress just as well as progress (for instance adaptation to parasitic life is *always* regress).

The main thing: that each advance in organic evolution is at the same time a regression, fixing *one-sided* evolution and excluding the possibility of evolution in many other directions.

This, however, is a basic law."

2 Lenin talks of the importance of dialectical materialism where the emphasis is on the second word in his era. He remarks that in the era of Marx and Engels the emphasis was on the first word. In the current era, between a positivism and an anti-positivism that are both anti-materialist, the emphasis it seems must be on both words equally.