Note: The following is a rough transcript of a lecture I gave in Berlin in the summer of 2002 to members and supporters of the Socialist Equality Party of Germany (Partei für Soziale Gleichheit – PSG). In the interests of historical accuracy, I have not made any changes to the original transcript except for some very minor formatting. I am publishing it now as part of my reply to the smear campaign launched by David North and Ann and Chris Talbot as they make extensive use of selective quotations both from my lecture here as well as the subsequent exchange I had with Chris Talbot. For my reply to North and the Talbots see The Downward Spiral of the International Committee of the Fourth International on the Permanent-Revolution web site.

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Dialectics and the Crisis of Science

Introduction - The Crisis of Science

To begin with, we must define the topic of our presentation. First of all, we must discuss what precisely we mean by the crisis of science. Second, we have an obligation to present a useful definition of dialectics.

To tackle the first item, it may prove useful to first state clearly exactly, what we do not mean by the crisis of science. We do not mean by this that:

1. Science in general or particular scientific projects are underfunded.
2. The hard sciences are favored above the soft sciences not to mention the humanities, contributing to the resulting devaluation of culture.
3. The results of science, technological improvisation, have had destructive social effects. This may encompass such contemporary concerns as the unleashing of nuclear weapons, pollution and environmental degradation caused by the exploitation of fossil fuels, the accelerated rate of extinction's of plant and animal species, the possibility of cloning a race of biological robot-slaves, and many other social issues.

All of these subjects are important in their own right. However, they do not illustrate what we have in mind in discussing the crisis of science, although they may certainly be related to that issue. What these topics illustrate are the social or practical effects of scientific activity. In addition, it is certainly undeniable that while the beneficial effects of this activity are generally recognized, its destructive potential has become just as clear.

Furthermore, in discussing the crisis of science, we are not referring to the frustrating bottlenecks that inevitably emerge in the course of some specific scientific theorizing or research. For instance, the current quandary into which cosmologists have been thrust by the unexpected discovery that the expansion of the universe appears to be accelerating is a perfect example of what we do not mean to discuss. This recent discovery seems to contradict the widely accepted Big Bang Theory of the origin of the universe, which predicts that the expansion of the universe will eventually subside and at some point, the universe will begin collapsing. If you came here with some expectation of getting some scoop on this riddle, you will be disappointed. I am not a physicist or a trained scientist and have no insight into this issue.

What we have in mind instead is an investigation into the manner and degree to which science as such has strayed from its original goals. What do we mean by "straying" from its original goals? To help understand where we are going, take the example of a public non-profit organization that is said to have strayed from its original goals. Suppose the board of directors of an organization whose nominal purpose is to help alcoholics overcome their addiction, decides that its past methodology of supporting abstention is a losing proposition, and that it would be wise to accept grants from the liquor industry in return for advocating a policy of moderate drinking. In this case, the meaning of the term "strayed" is evidently that the organization has turned its back on the principles and goals enshrined in its founding charter. As long as the tension exists between the founding principles and its new orientation, the organization is said to be in crisis.

Since non-profit organizations are legal entities answerable to the terms of their founding charters, it is possible for interested parties to bring suit in an attempt to seek legal redress to the situation - to force the organization to return to the principles of its foundation. If successful, the crisis is said to be resolved in a positive direction. If legal action, or other forms of pressure are unsuccessful then the crisis is resolved in another manner - the organization has successfully redefined itself and is now free to act, for good or for ill, in ways previously undreamed of. In either case, we can say that the crisis has been resolved.

Science of course is not a legal entity in the manner of a non-profit corporation. It is nevertheless a form of human activity, one that is institutionalized within a definite social structure. It can also be said that this form of institutionalized social activity has definite founding principles that animate it. Though these founding principles are not recorded in a legal charter such as one finds in a corporate entity, they are in some sense universally recognized and have the force of historical precedence.

We can say that the codification of the purpose of science, not the elaboration of its work which is a continuing endeavor, but the foundation of its purpose, was first enshrined in ancient Greece when the idea that the world can be understood according to its own rationality was first introduced. Previously all attempts to understand the world were bound up with myth and religion. It is with the Greeks that the separation between rational understanding and religious belief is first consciously introduced. (Analogous developments also took place in some of the other great civilizations such as the Indian and Chinese.)

In its beginnings, there was no sharp distinction between science and philosophy. In fact, the sharp distinction between the two that we now take for granted was only introduced in the last two or three centuries. Up to the renaissance the close and unbreakable relationship between science and philosophy was a given. Remnants of this close connection between philosophy and science survive up to the present day. It is why in many European universities for instance, the department of physics is called the department of natural philosophy. We begin to get a glimpse of the nature of the crisis once we realized how strange that formulation, "natural philosophy", sounds to us today.

For the ancients, as well as the medieval thinkers and even the early moderns, the distinction between philosophy and science was not so much with subject matter but with its scope. Philosophy, what in the works of Aristotle was called metaphysics, was the investigation of all of reality, Being as such. Science on the other hand was the investigation of a limited part of Being. The science of botany for instance was the attempt to understand that part of Being delimited by the life of plants. In fact, there were many individual sciences, each devoted to the investigation of a different part of Being. It is to Aristotle that we are indebted for first delineating the responsibilities of the different sciences. He also pioneered much of the work of these initial forays into science.

Furthermore, the sciences were not just randomly placed, but each represented a hierarchy of knowledge, corresponding to a hierarchy being. The most comprehensive of the sciences, that which attempted to understand all of nature as such, including plants, animals, the heavens and the earth, was called physics. Yet, Aristotle realized that there had to be another science that provided the foundation for all the separate sciences. This could not be the work of physics for instance, because physics already presupposed a certain relationship between itself and nature and the other sciences, which in some way it encompassed. How was this relationship to be explained? Aristotle proposed therefore something even more comprehensive to explain this, a kind of science of the sciences, which has come to be known as metaphysics. Although the term metaphysics has in more recent times come to denote empty speculation or unfounded belief in supernatural forces, this was not at all what Aristotle had in mind. In fact, originally, the term metaphysics simply refers to the book in Aristotle's corpus that comes after the physics, the Greek "meta" meaning "after". Nor was the term "metaphysics" created by Aristotle but by a later editor. Aristotle referred to the topics covered by the Metaphysics treatise as First Philosophy. It was a logical extension of his discussion of the individual sciences. Whereas each of the individual sciences investigates a particular part of Being, First Philosophy is the investigation of Being qua Being. It is the science of the principles that underlay the totality of Being, and this is roughly what is meant by the traditional, pre-modern notion of philosophy. Thus, for Aristotle and pre-modern thought in general, philosophy and the sciences are intimately intertwined.

Our modern notion of this relationship is very different however. Science is split off from philosophy and each go their separate ways. We will shortly discuss the historical dynamic, the why and how behind this rupture of science from philosophy. I just want to momentarily focus on the consequences of this separation. It is this separation of science from philosophy that provides us with a first approximation of what I refer to as the crisis of contemporary science. Note however that the modern sensibility does not consider this a crisis at all, but on the contrary, we celebrate what we consider the liberation of science from the constraints of metaphysics. For reasons that will become clear, we have elevated the sciences at the expense of philosophy. In fact the very legitimacy of philosophy, of a systematic inquiry into the totality of what is, is automatically suspected of being a form of mysticism if not worse. Without wishing to belabor this point, let me illustrate this animus toward any kind of discussion of the totality of being by quoting MIT professor emeritus Noam Chomsky.

"…It is perhaps worthwhile to recall some further truisms; in rational inquiry, in the natural sciences or elsewhere, there is no such subject as "the study of everything". Thus it is no part of physics to determine exactly how a particular body moves under the influence of every particle or force in the universe, with possible human intervention, etc. This is not a topic. Rather in a rational inquiry we idealize to selected domains in such a way (we hope) as to permit us to discover crucial features of the world. Data and observation, in the sciences, have an instrumental character. They are of no particular interest in themselves, but only insofar as they constitute evidence that permits one to determine fundamental features of the real world…" (New Horizons in the Study of Language and Mind, Cambridge University Press, 2000, p. 49.)

I cite Chomsky merely as an illustration of a certain way of thinking that is more or less taken for granted in many quarters. Examining his statement leads to some interesting results however. For no sooner does he pronounce "the study of everything" is not a subject, than he refers to the very "everything" he claims we cannot study. "It is not part of physics", he says, "to determine how a particular body moves under the influence of every particle or force in the universe". But what is this "universe" he suddenly brings in? Is it not another name for the "everything" that he says cannot be a subject. And if it cannot be a subject, how can we know anything about it at all? Next, he says that in "rational inquiry we idealize to selected domains in such a way as to permit us to discover crucial features of the world". Again I might ask, what is the "world" that is referred to here. Is this not another name for the "everything" about which we can have no knowledge? But we are not finished. Chomsky, it seems cannot let the matter drop. In yet another statement reinforcing his argument that "the study of everything" is not a subject, he writes that, "They (data and observation) are of no interest in themselves, but only insofar as they constitute evidence that permits one to determine fundamental features of the real world." Here we finally graduate from an allusion to the "universe", then to the "world" and now to the "real world". But how do we know what the "real world" is? If we accept Chomsky's terms then it seem that this is not even a legitimate question. And if our knowledge of the real world is not a legitimate question then how can we legitimately make reference to it? Try as he might to rid himself and us of the "study of everything" it seems that he cannot even describe why this is illegitimate without appealing to some sort of concept of the "everything" about which we can have no knowledge. It is a perfect example of how the dialectic ensnares those who would deny it. But I am getting ahead of myself here for we have not even introduced the topic of dialectics.

Origins of Science and Philosophy

We need to return to our discussion of the origins of the science and philosophy in order to clarify the nature of the crisis. We have alluded to the first formulation of science and philosophy among the ancient Greeks. And here we have in mind particularly the work of Plato and Aristotle, especially Aristotle. For it is in the work of Aristotle that the classification of the different sciences and their relationship to each other is first formulated. Not only that, but the content of these individual sciences are first filled in by Aristotle. Finally, he brings to bear a notion of the totality within which the universe coheres. There is today a tendency, inherited from the Enlightenment, to belittle Aristotle and all the ancients. He is said to be dogmatic, unscientific, and indulged in empty speculation, which hampered the development of the sciences. This viewpoint certainly underestimates both Aristotle and those who followed him for the next 2000 years. For the world outlook first elaborated by Aristotle was the dominant mode of thought of the Western world until the scientific revolution of the 16th and 17th century. Any philosophy that has that long a run could not simply have been based on the passive acquiescence of all the great intellects of the intervening centuries.

It is true however that by the time we encounter the descendants of Aristotle in the 17th century, the Aristotelian (now the Aristotelian-Ptolemaic system) of thought had become overgrown with dogma and senility. It is not my purpose to highlight the differences between the original dynamic insights of Aristotle and its medieval scholastic elaboration. Let us simply sketch the view of the world that was accepted as traditional Aristotelian science by 17th century thinkers.

Aristotelian physics is tightly intertwined with First Philosophy. Yet it should be understood that Aristotelian physics is a real physics, in the sense that it offers a systematic explanation of various physical phenomena. It starts with common sense perceptions, such as the observation that heavy bodies fall to the earth, but it does not remain at the level of common sense in accepting such phenomena. It looks for reasons underlying what we see. That is what makes it a science. The point is summed up by Alexandre Koyre in his summary of Aristotle's concept of motion:

"The distinction between 'natural' and 'violent' motion is located within a general conception of physical reality, a conception of which the key aspects appear to be: (a) the belief in the existence of specific 'natures' and (b) the belief in the existence of a COSMOS, i.e. the belief in the existence of principles of order by virtue of which the totality of real beings form a (naturally) well-ordered whole."

"Whole, cosmic order; these ideas imply that everything in the Universe is, or ought to be, distributed and arranged in a highly determinate manner; that things are not indifferent as to whether they be here or there, but that, on the contrary, everything in the Universe has its proper place in conformity with its nature. A place for each thing and everything in its place; the idea of 'natural place' is the theoretical expression of this necessity in Aristotelian physics. The idea of 'natural place' represents a purely static conception of order. For if everything were 'in order' everything would be at rest in its natural place, would remain there, and would not move away from it. Indeed why would anything leave 'its' place? In fact quite the opposite; it would exert a resistance to anything that tried to remove it from 'its' place - something that could only be accomplished by violence - and would attempt to return there whenever, as a result of such violence, it found itself located elsewhere."

"Thus all motion implies a cosmic disorder, a disequilibrium, whether it is itself the direct effect of such a disequilibrium resulting from the application of an external force (violence), or is on the contrary the effect of a compensatory effort of a thing to rediscover its lost and violated equilibrium, to bring things back to their natural, appropriate places, where they will be able once again to find rest. It is precisely this return to order which constitutes what we have called natural motion."

"Upsetting of equilibrium, return to order: it is understood that order takes the form of a stable state, a state that tends to persist indefinitely. There is, therefore, no need for an explanation of rest, at least of the natural rest of a body in its proper place. Its own nature is itself the explanation; it is this which explains, for example, the earth's being at rest at the centre of the world. It is also understood that motion is necessarily a transitory state. Natural motion naturally ceases when its goal has been reached. As for violent motion, Aristotle is too much of an optimist to believe that this abnormal state could be an enduring one. Moreover, since violent motion is disorder which creates disorder, to allow that it could last indefinitely would be, in fact, to give up the very idea of the Cosmos: hence the reassuring formula for violent motion-nothing which is *contra naturam potest esse perpetuum*."

"… 0n the other hand, motion is not strictly speaking a state: it is a process, a becoming in and by which beings are formed, actualised and completed. Certainly being is the goal and end- point of becoming; and the goal of motion is rest. But this unchangeable rest of the fully realised being is something, quite different from the impotent and ponderous immobility of a being which is not capable of motion. The former is actuality, the latter is simply a lack or privation. Therefore motion-process, becoming, change-is ontologically intermediate between these. It is the being of all that changes, and which is only in being changed and modified. The famous Aristotelian definition of motion- the fulfillment or actualisation of what exists potentially, insofar as it exists potentially - (a definition which Descartes found utterly incomprehensible) expresses marvelously well the fact that motion is the being-the actualisation-of that which is not God. "

"Therefore to move is to change, … to be, says Aristotle, 'alteration of what is alterable qua alterable'. On the one hand this implies a fixed point of reference in relation to which the moving thing alters and alters: and this means, in the case of local motion, that there must be a fixed point in relation to which the moving things moves, an absolute coordinate centre, the centre of the Universe. On the other hand, since all change, all process, must have a cause which is also its explanation, this implies that all motion must be caused by a motor which sustains the motion as long as it endures. In other words motion, unlike rest, does not persist of its own accord. Rest, which is a state or a privation, has no need of a cause to explain its persistence. Motion, which is a process, an actuality, even a continuous actualisation, is impossible without one. If the cause is removed the motion ceases…"

"In the case of 'natural' motion this cause, this motor, is the nature of the body itself, its form, which seeks to bring it back to its place. This is what sustains the motion. In contrast to this a non-natural motion requires, throughout its duration, the continuous action of an external motor, contiguous with the mcving body. If the motor is taken away the motion the motion will cease." (Alexandre Koyre, Galileo Studies, Harvester Press, 1978, p5-7, English translation of French original Etudes Galileennes.)

An example of natural motion is the downward motion of a heavy body when dropped from a tower. The object is impelled downward because it has the quality of 'gravitas' and seeks its natural home at the centre of the earth. On the other hand how do we explain the upward motion of a candle's flame? It is moving upward because it has the quality of 'levitas' and seeks its natural home in the air. To the modern ear such explanations sound absurd, a kind of word game. But they are only absurd when taken as divorced from the cosmological outlook that animates Aristotelian physics. Within that set of consistent theoretical structures they make perfect sense. We know these explanations to be at least on the face of it wrong, but given the level of technological development in Aristotle's time, it was hardly possible to theorize much beyond this point. When it becomes manifest that the physics is wrong, the metaphysics is rejected wholesale along with the physics. This is what happens starting with the scientific revolution of the 16^{th} and 17^{th} century.

One consequence of the well-ordered Cosmos, which by the time of the Renaissance is handed down to European thought as the Great Chain of Being, is that the universe is necessarily finite. For Aristotle, order was synonymous with being properly delimited, and to be delimited is to be finite. When Aristotle was adopted by Christian theologians in the middle ages, many debates ensued seeking to prove why the universe could not be infinite. One of the common arguments was that the finitude of the universe, God's creation is implied by the infinity of God. God must be greater than his creation.

The 17^{th} Century Revolution in Science

One of the consequences of the scientific revolution that would overturn The Great Chain of Being will be that the universe would be conceived as infinite. The English poet John Donne, writing at the start of the 17^{th} century, captured the spirit of the scientific revolution in the following words:

> "…new Philosophy calls all in doubt,
> The Element of fire is quite put out;
> The Sun is lost, and th'earth, and no mans wit
> Can well direct him where to looke for it.
> And freely men confesse that this world's spent,
> When in the Planets and the Firmament
> They seeke so many new; then see that this
> Is crumbled out againe to his Atomies.
> 'Tis all in peeces, all coherence gone;
> All just supply, and all Relation."

Donne's last statement - "Tis all in peeces, all coherence gone; All just supply, and all Relation" - is an eloquent expression of what we can call the first crisis of science, the one that emerges in the 17^{th} century. Humanity had lost its tether. The geocentric view of the universe, so comforting to many, was rudely displaced by the heliocentric outlook of Copernicus. The spirit of self-confidence has been evicted from its natural home and thrust into an infinite and empty void. Donne's literary expressions not coincidentally hearken back to the religious sentiment of a primal loss of innocence and subsequent banishment from the Garden of Eden. What this points to is an incongruity between the new developments of science that look to the future to philosophical and cultural attitudes inherited from the past. To put this in other words, the philosophy lagged behind the new science and was not catch up to it until the Enlightenment of the 18th century when a new spirit of optimism begins to emerge based on a firm conviction in the order and design of the universe, as codified in Newton laws of motion. Following the triumph of Newton, science and philosophy exhibit a renewed confidence in man's ability to discover the design of the universe and in this sense the crisis of 17th century science was for the moment resolved. We will see shortly that the crisis of contemporary science is in many ways analogous to this crisis of the 17th century.

But first let us take a closer look at the Revolution in science of the 17th century. Before characterizing the physics and philosophy associated with the scientific revolution, it is first necessary to dispose of a myth, one that took hold during the Enlightenment and that still exercises considerable influence. This myth has it that the scientific revolution of the 16th and 17th century can be characterized by a break from the Aristotelian outlook and a return to or appropriation of one of the forgotten philosophies of the ancient world - the atomism of Democritus and Epicurus. This is a very neat theory because by the 18th century atomism does indeed characterize the outlook associated with the new science. And the atomism of Democritus and Epicurus was unquestionably a brilliant anticipation of classical physics. The only problem with this scenario is that this is not how things developed historically. The works of Democritus were lost for centuries and only rediscovered in the 15th century. Furthermore, the influence of Democritus and the ancient atomists on the thinking of the pioneers of the new science, men like Bruno, Galileo, Descartes and Newton were slight. Yet, despite the historical record, which was masterfully reconstructed by Alexandre Koyre, this myth persists to this day because it fulfills the ideological requirements of certain parties. The 18th century materialists sought an ancient lineage for their mechanistic theories and thus appropriated the works of Democritus and Epicurus, as did the positivists of the 19th and 20th centuries. Likewise, many vulgar Marxists, particularly from the Stalinist camp, adopted this historical genealogy.

The actual historical development that lead to modern atomism and mechanism is far from straightforward and much more intriguing than the potted histories of the propagandists. If you look for the roots in ancient philosophy behind the works of Bruno, Copernicus, Galileo, Descartes and Newton, it would not be the materialist Democritus but the figure of the arch idealist Plato and the mystic Pythagoras who come to mind. How does Plato become the godfather of the new physics? The answer is that it is with Plato, who following the tradition initiated by Pythagoras, we first find expressed the idea that reality is essentially mathematical. We know in fact that inscribed over the door to Plato's academy were the words,

"Let no one who has not grasped the mathematical enter here."

Mathematics was therefore considered a basic prerequisite for the study of philosophy. With good reason, as for Plato mathematics is the language that describes reality as it really is, as opposed to the ephemeral and changing world of our perception.

What is this however but the very attitude that defines the new physics? For if we had to describe the new physics in terms of a single fundamental guiding idea, it is that the universe can be described in terms of precise, measurable, mathematical relations. The Aristotelian universe is on the other hand rooted in more natural qualitative descriptions. There is no conception of a mathematical relationship governing the movement between two bodies. Rather, a body is either naturally heavy or light and is therefore either pushed toward another body or pulled away from it. It is true that mathematical relations were recognized in astronomy. This was a cornerstone of the Ptolemaic system. Yet these mathematical relations were applicable solely to the motion of the heavenly bodies. When it came to terrestial movement, not only were mathematical relations not recognized, there was an active polemic on the part of the medieval followers of Aristotle against any attempts to apply mathematics to these phenomena. This highlights another peculiarity of pre-modern physics, i.e. the complete dichotomy between the laws governing the heavens and those governing what came to be called the sublunary world.

How then to characterize the new physics? Briefly, it is a complete overturn of every principle held dear in the Aristotelian-Ptolemaic world outlook. And it does not emerge overnight. The idea that the universe is infinite and not a well ordered closed system first appears in the works of ancients, particularly the atomists Democritus and Leucippus. They postulated an infinite number of atoms within an infinite space. After the Roman followers of Democritus and Epicurus, Lucretius and the Stoics, the idea of an infinite universe is not elaborated again until the late middle ages, particularly in the works of Nicholas de Cusa. He formulates his views about the same time that Lucretius is rediscovered, although it is not known if he was acquainted with Lucretius. In any case, the idea of an infinite universe is developed by Giordano Bruno and Copernicus, but only very tentatively. Bruno in particular is the first scientist to take seriously the arguments of the Greek atomists for the infinity of the universe. But it would be wrong to call Bruno an atomist himself as he combines elements of the Democritean doctrine with a vitalistic and magical cosmology. The infinite universe does not receive its full expression until the work of Newton who postulates an infinite space and time without beginning or end - the closed system of Aristotle and Ptolemy finally being overthrown.

Likewise, the notion of plenitude, or all of nature consisting of various grades of being without any gaps, the Great Chain of Being in other words, is replaced with that of a corpuscular universe consisting of atoms and the void. By the time we get to Newton, we can say that the ancient atomists' conception of matter has been vindicated, as much by the introduction of empty space as by the positing of atoms. It was in fact one of the tenets of the old science that a vacuum could not exist. The apparent emptiness of space was thought to consist of a substance called ether. The idea of an ether persisted until the very end of the 19th century. It was perhaps the last vestige of Aristotelian science to be overthrown, on the very eve of relativity theory.

Perhaps the crowning achievement of the new science was the discovery, starting with Galileo and completed by Newton, that mathematical relations can describe the motion of earthly bodies, such as balls rolling down an inclined plane, or projectiles. The insight was expressed beautifully by Galileo when he said,

"No one will be able to read the great book of the Universe if he does not understand its language, which is that of mathematics." (Kaku, Hyperspace, p.327.)

In fact, the same laws governing the motion of earthly bodies is at work governing the heavenly bodies. The laws of universal gravitation encompass all nature and unify the realms of heaven and earth.

What follows is that motion is not a product of the natures of individual bodies, but is a product of forces acting at a distance between bodies. No longer can motion or any behavior be explained as a result of the nature of any particular substance. Motion is no longer a property of things but a consequence of the interrelatedness of bodies. It is thus no longer unnatural to be in motion or natural to be at rest. This also leads to the breakdown of the qualitative differences between things. If the behavior of all bodies in the universe can be described by the equations of universal gravitation, then the essential features of all things are reducible to their quantitative determinations.

The Philosophy of Mechanism

With the advent of the new science the well-ordered cosmos of the ancients gives way to a mechanical view of the world. By this we mean that all reality is seen to consist of individual particles or simple entities. These entities have no natural place or goal inherent in their nature. They simply exist either as recipients or agents of forces working according to specific mathematical laws. From a living organic whole, the universe is turned into a purely mechanical device. With Descartes we get the first inkling of what would later be called mechanical materialism. Descartes considered animals to be nothing more than living machines. As with all machines, animals experience neither pleasure nor pain. Humans are given a reprieve from this fate only because Descartes, as a deeply religious man, believed that men and women had souls and thus could not be just machines. However, some of Descartes descendants, the mechanical materialists of the 18th century, people such as Holbach and LaMettrie, took the final step and consigned man to the status of a very complex machine.

The universe as a whole was seen as a machine. The image of the well-run clock dominated the thinking of philosophers and scientists of the 17th and 18th century. The French mathematician Laplace in fact postulated a universe which functions exactly as a perfect timepiece, and if enough information was known about the start of a process, its eventual outcome could be perfectly determined. When asked by Napoleon where God fit into his universe, Laplace replied that "I have no need for that hypothesis."

I have not yet mentioned the role of hypothesis and experimentation in the new science. This is not because experimentation did not play an important role in the development of the new science. However, the place of experimental procedure in the birth of modern science, like the role of the ancient atomists, has taken on a mythic status. To properly appreciate the role of experimentation in the scientific revolution, it is necessary to disentangle fact from myth.

The first thing to be said here is that experimentation and observation are always performed within a historical context, one in which we are informed by theories and concepts of what we are looking for. In this sense we can say that all experimentation and observation is "theory - laden" to begin with. This was an insight that the late MIT professor Thomas Kuhn developed and he was absolutely correct to point this out against the prevailing orthodoxy that saw experiment and observation as some kind of prior state of innocence from which we build generalizations. I should add that Kuhn was by no means the first thinker to have had this insight - it is already found in Hegel for instance - though that does not detract from his achievement.

The myth of "pure" experimentation, or "pure" observation as the bedrock of modern science is one that survives to the present day. It is one of the tenets of modern empiricist philosophy that I shall describe presently. We have noted that the creators of the new science, men such as Bruno, Galileo, Newton, did not think of themselves as experimenters who then derived generalizations based on their experiments. They thought of themselves as Platonists who sought to discover the mathematical laws that governed nature. Certainly experiment and observation play a role in the work of Galileo for instance. For Galileo however, experiments such as the dropping of weights from a high tower were meant to validate his theory. It was not the basis for the discovery of his theory. Furthermore it has been pointed out by some historians that Galileo did not have the technical ability to measure the elapsed time of falling bodies with sufficient precision to prove his case. In fact, throughout the history of science it seems that great discoveries rarely if ever follow the supposed path prescribed by the "experimentalist" school of empirical philosophy. (I have in mind positivist philosophers of science such as Hans Reichenbach, who dominated discussion of these issues in the English speaking world for much of second half of the 20th century.) Einstein for instance, was said to be wholly unimpressed when told that an experiment had provided the first empirical confirmation of his Special Theory of Relativity. Showing not the slightest bit of excitement he said,

> "But I knew that the theory is correct."

I have said at the beginning that science and philosophy are interrelated. And it is certainly the case that the new science of the 17th century gave birth to a new philosophy. Likewise, the scientific work of men such as Galileo and Newton was also philosophically inspired as we have noted - this is a two way street after all. Were we to enumerate the philosophical heritage spawned by Newton, we would include the philosophers, Locke, Hume, the French materialists, the positivists of the 19th century, the logical atomism of Russell, Whitehead and the early Wittgenstein at the turn of the last century, and the turn to language analysis which develops after the project of logical atomism is recognized as untenable.

Of course in some ways all modern philosophy owes its origin to Descartes and through him to the development of the revolution in science. Certainly there are other schools of modern philosophy, both idealism and Marxism, that are antithetical to the empiricist and mechanical tradition I have just enumerated. I wish however to focus for the moment on this one branch that emerges from the tree of modern thought because it is in the philosophy of empiricism that the most influential and dominant forms of thought have asserted themselves in the contemporary world.

One feature of the new mechanical philosophy that we are examining is that in reacting against the world of Aristotelian science, it soon took on the entire philosophical foundations inherited from Aristotle. The attack on Aristotle was intimately related to the growth of anti-clericalism and all things Catholic. By the 17th century, Aristotle and Catholic philosophy were synonymous. A typical example of the rhetoric against Aristotle is the following tirade from Hobbes's "Leviathan",

"I believe that scarce anything could be more absurdly said in Natural Philosophy, than that which is now called Aristotle's Metaphysics; nor more repugnant to Government that much of what he hath said in his Politics; nor more ignorantly, than a great part of his Ethics." (Leviathan, Cambridge University Press, p. 461-462.)

In opposition to the well-ordered Cosmos of Aristotle, Hobbes puts forth a crude type of empiricism. Hobbes attack on Aristotle has its antecedents, as we have already seen, in the ancient world, in the philosophy of atomism. According to the atomists Democritus and Lucretius, the world was made up solely of atoms and the void and their combinations. The modern version of atomism received its most finished articulation by Hume and the school of empiricism. The Humean version of atomism posits "sense data" as the ultimate building block of reality instead of atoms. Methodologically however, empiricism leads to conceptions very similar to those held by the ancient atomists. The aim of science, according to the atomist/empiricist outlook, is to reduce all descriptions of reality to the working of ultimate bits of reality whether these be "sense data" or atoms, and the forces that are responsible for their motion and interaction. This reductionist vision of bringing all areas of knowledge, including the social sciences, under the rubric of physics, still remains, three centuries after Newton, the dominant view of modern science as well as philosophy.

To illustrate my point, let us quote a contemporary reductionist follower of Hume, the sociobiologist and author E.O. Wilson. In an interview based on his recent book "Consilience: The Unity of Knowledge", (Knopf, 1998) Wilson gave the following formulation of his vision:

"In theory, we should be able to predict many of complex patterns at higher levels of organization, which we call emergent, from a knowledge of the constituent elements and their interactions… Methodologically, reductionism has proven spectacularly successful across a large part of science." (Skeptic Vol6, No.1, 1998, p 79-80, "The Ionian Instauration" an interview by Frank Miele)

An even more militant reductionist is the philosopher Daniel Dennett. His recent book, Darwin's Dangerous Idea, Simon and Schuster, 1995, even includes a chapter titled, "Who's Afraid of Reductionism?" where we find this gem:

"There is no reason to be compromising about what I call good reductionism. It is simply the commitment to non-question-begging science without any cheating by embracing mysteries or miracles at the outset."

That Dennett cannot even conceive of an objection to reductionism except by recourse to miracles shows the depth with which an atomistic outlook is assumed to be the only possible explanatory principle by which the world can be understood. The principle thesis of atomism is first of all presupposed and then arguments based on this presupposition are used to justify it. This is indeed a vicious circle.

Just as reductionism is one consequence of the mechanical-empiricist philosophy which now dominates much of scientific discourse, another equally disastrous consequence is the belief that science can proceed without philosophy. The above quote by Hobbes, attacking natural philosophy is one of many one can present to illustrate this point. Empiricism does not just attack the philosophy of Aristotle. Ultimately it ends up attacking all philosophy as such, seeing philosophy in the same terms as the Church, as an encumbrance and tether on the development of the sciences. Of course there were good historical reasons for this hostility toward the institution of philosophy. These sentiments emerged at a time when it was important for science to assert its autonomy against the stifling atmosphere of the Church, which had only a few generations previously burnt Bruno alive at the stake and forced Galileo to recant his views. And philosophy was closely identified with the Church and Aristotle. For Aristotle's greatest exponent in the middle ages, Thomas Aquinas, Aristotle is always referred to simply as "the philosopher".

But excising philosophy from the sciences has certain detrimental consequences as I hope to demonstrate. If we return to the original conception of Aristotle, the relation of First Philosophy to a particular science is an example of a Whole to Part relationship. Now what does it signify to study a Part without any knowledge or even concept of a Whole. This is the conundrum that Chomsky got into in the material I previously quoted. After denying the possibility of investigating the Whole, he is forced to contradict himself and refer to this Whole for the simple reason that it is not possible to conceive of a Part without referring to the Whole. Whole and Part in fact are correlative concepts. In the course of its evolution, the science of the 17^{th} century separated the Whole from the Part.

If we follow the history of philosophy from the 18^{th} century up to the present, we get increasingly a rejection of the value of philosophy as such. This becomes most pronounced in the schools of logical positivism that emerged in the first half of the 20^{th} century. They considered all questions that could not be empirically verified or to be at best empty tautologies or worse still, nonsense. Under this category falls any of the traditional issues of philosophy, as well as psychology and literature. If we cannot categorize it and measure it, it is not a real issue. This same attitude is frequently found among working scientists as well. But try as you may you cannot get away from the question of the relation of the whole to the parts.

Although philosophy is explicitly rejected, it does not at all disappear from the scene, since as we have noted the part cannot really be meaningfully discussed divorced from the whole. Instead, a philosophy is presupposed and appealed to in a hidden form. The tenets of the atomistic conception of reality are simply taken for granted and become unquestioned assumptions guiding all inquiry. Let us enumerate the metaphysical presuppositions behind empiricism:

1. The world consists of simple entities which Bertrand Russell called "atomic facts". Each simple entity is independent of every other one.
2. All objects in the world are either simple entities or some combination of simple entities that come together accidentally.
3. Universals do not exist except as a mental construct. They are merely convenient placeholders for objects that have some quality in common. The world is a world of particulars.
4. Laws governing the behavior of the world or of its parts are likewise only mental constructs. We can never prove the necessity of any event. All events are contingent. This last point follows from Hume, who argued that a particular cause never entails a particular effect. For instance, the motion of billiard ball striking another ball does not necessarily cause the new ball to move. All we know for certain is what we see - this follows from the basic premise of empiricism, i.e. that knowledge is ultimately derived from sense data, and what we see is that the blue ball hits the black ball and the black ball moves, but we do not see that blue ball caused the black ball to move. We infer that, and for practical purpose our inference serves us well, but we can never prove it.

These positive principles imply the rejection of certain other principles with which they are in conflict. Among those principles that are opposed by empiricism are the following:

1. The world is a coherent whole that has its own principle of organization.
2. Particulars cohere only in relation to universals.
3. The world is composed of interrelated wholes, each of which contains its own principle of organization.
4. There exists a hierarchy of levels of self-organizing wholes. The principles appropriate to explaining one cannot be applied without violence to a whole resting on another level. This last point is obviously the major tenet of anti-reductionism. The notion that there is one privileged form of organization to which everything else must be reduced is explicitly rejected.

This is a far from exhaustive list. But it should suffice to illustrate the antithetical direction of empiricism and the philosophy of what I shall call "wholism" (of which dialectical philosophy is a more specific development). I have already indicated what I meant by the crisis of science, at least as it applies to the 17th century. The science of the 17th century was ahead of the philosophy of its time. Eventually the philosophy caught up to the science, the result being that a mechanical science gave rise to a mechanistic philosophy, one that still holds sway today. How do we then define the crisis of contemporary science? This implies that there have been developments in science which challenge the mechanistic philosophy that has evolved over the last 300 years. This is precisely my point. It is not possible or course to go into these developments in science in any detail, but let me enumerate what I think are some key events that call into question the philosophy of empiricism and mechanism. I will concentrate here on developments in physics and will not go into biology or the social sciences. The reason for this is that the developments in the biological sciences, particularly evolution and genetics, have already been dealt with, most notably in the work of Richard Lewontin. (For example, see his "The Dialectical Biologist") Likewise there has been much literature on the developments in the social sciences . In comparison, very little has been written about physics from the point of view of its most recent philosophical implications.

The Eclipse of Newton

The first major challenge to Newtonian mechanics comes interestingly enough, not from physics, but from the geometric theories of a German mathematician named George Bernhard Riemann. The beginning of the end of Newtonian physics takes place on June 10, 1854. That was the day when Riemann gave a public lecture in which he presented a geometric system that was an alternative to the Euclidean geometry upon whose shoulders Newtonian mechanics rested. Riemann's geometry postulated a space composed of higher dimensions than the normal three of Euclidean geometry. He postulated a space that was curved, much like the walls of the inside of a sphere are curved. Within this geometric system, all the axioms of Euclidean geometry are suddenly no longer obvious. For instance, in curved space parallel lines will meet. This was a radical mathematical theory for no one had ever questioned Euclidean geometry before. After all, its small number of assumptions, such as the principle that parallel lines never meet, seem in the light of day to day common sense experience to be obvious.

The geometry of four dimensions completely throws out the axioms of Euclidean geometry. The question then remains, does this strange new geometry have any relation to the real world as conceived by theoretical physics. Riemann himself was far from what we call today a pure mathematician. He firmly believed that his geometry was applicable to the physical world. If this were so, a number of interesting things follow. First, the apparent linear motion, i.e. motion tending to a straight line, must be an illusion because if we lived in curved space, motion would also be curved. This fact must account for the apparent distortion of motion that Newton attributed to forces acting at a distance between two bodies. With the geometry of four dimensions, it was possible to get rid of the concept of forces instantaneously acting at a distance. Force is nothing more than a property of geometric space.

Some very interesting things happen in a higher dimensional space. We are not able to visualize any of this behavior simply because our brains have only evolved to visualize movement in three dimensions. However, we can extrapolate some of the properties of physical behavior in higher dimensions by turning to an analog based on a hypothetical two-dimensional world. This world in fact was envisioned by the 19th century novel "Flatland." One of the peculiar things about life in a two dimensional world is that you can never turn around in such a world. You can rotate yourself on the plane in which you exist, but if you are stuck with your eyes pointed upward toward the sun, and you wish to turn around to go sleep, it is not possible to do so. You are forever poised with face toward the sun. But if you could step out of the two dimensional world into a three dimensional world, then you could of course turn around and afterward return to the two dimensional world, and presto, you have done the impossible and turned yourself around. What this meant was that if it was possible to escape into a higher dimension and then return, you could seemingly bypass ordinary restrictions of time and space. Taking the Flatlands analogy to heart, if it were possible to travel to the fourth dimension and escape our normal three dimensional world it seem one could then engineer a return to the third dimension and come up at a completely unexpected place. If that were the case then no prison could hold you. Nor could the vault of any bank be safe from an invader from the fourth dimension.

This insight derived from Riemann ignited a tremendous interest in the latter part of the 19th century. However it was not among physicists that Riemann's mathematical speculation were at first taken up. Riemann himself believed that the geometry of four dimensions was a description of physical reality, however he was not able to demonstrate it. There were other physicists who thought this may be a fruitful topic for exploration, but they soon gave up as it seemed there was no conceivable way to test if we actually live in a three dimensional or a four dimensional space. Speculation about the fourth dimension in fact shortly becomes discredited among serious physicists as it was appropriated by mystics and charlatans. There was in fact a sensational trial, for fraud, in London in 1877, involving the fourth dimension. In the dock was a famous psychic, Henry Slade, who held seances with prominent clients. He claimed that in these seances he could transport spirits back from the fourth dimension to commune with his guests.

One of the most bizarre things about this trial was the support Slade managed to enlist from the scientific community. Lead by Johann Zollner, a professor of physics and astronomy at the University of Leipzig, an international cast of scientists, some of whom went on to win the Nobel prize, were lined up in Slade's defense. As part of an effort to prove that Slade's claims about access to the fourth dimension were genuine, this group of scientists concocted a series of controlled experiments. One of these involved two separate unbroken wooden rings. Could Slade push one wooden ring into the other so that they were intertwined without breaking either one. If Slade could do this, it would seem to confirm that he was able to defy the physical laws of the ordinary three-dimensional world, in effect by escaping into a higher dimension. Needless to say Slade was eventually convicted, but Zollner's hypothesis that the ordinary laws of physics are turned on their head in a higher dimensional universe was not wrong. It would however take another several decades before serious physicists approached this problem again.

Riemann's higher dimensional space became a fad among writers and artists. The previously mentioned novel, Flatlands, was but one of many inspired by speculation about other dimensions. Among these we can mention the novel by H.G. Wells, "The Invisible Man." And in the 1901 story "The Inheritors", by Joseph Conrad and Ford Maddox Ford, "a race of supermen from the fourth dimension enters into our world. Cruel and unfeeling, these supermen begin to take over the world." (Michio Kaku, Hyperspace, p.62)

Among artists the period from 1890 to 1910 saw artistic movements inspired by the fourth dimension. Art historian Linda Dalrymple for instance, has argued in her book, The Fourth Dimension and non-Euclidean Geometry in Modern Art that " it was among the Cubists that the first and most coherent art theory based on the new geometries was developed." (Kaku, p. 62) "To the avante garde, the fourth dimension symbolized the revolt against the excesses of capitalism. They saw its oppressive positivism and vulgar materialism as stifling creative expression. To them the fourth dimension was a way of pushing beyond the boundaries of our current reality. It also had the merit of having some scientific credentials, with which the avante-garde artists could tweak the noses of the positivist scientists. It also enabled them to challenge the traditional artistic orthodoxy in terms of defying conventional notions of perspective. The fourth dimension also inspired the surrealists. There is a famous painting by Dali for instance, called Christus Hypercubus, that depicts Christ crucified on a tesseract, which is a four dimensional version of a cube. Summarizing these movements in 1937, the art critic Meyer Schapiro said that, "Just as the discovery of non-Euclidean geometry gave a powerful impetus to the view that mathematics was independent of existence, so abstract painting cut at the roots of the classic ideas of artistic imitation."

The discussion of the fourth dimension even found its way into the history of the Russian Bolsheviks. It transpired that following the defeat of the 1905 revolution, there developed a faction within the Bolshevik party who were called the god-builders or Otzovists. This group argued that the Bolsheviks should sponsor a new socialist religion that would be attractive to the superstitious and backward peasants. They reinforced their views by citing the speculation of the physicist and philosopher Ernest Mach. Mach had written about the fourth dimension and about a new property of matter called radioactivity, which seemed to defy Newton's laws of conservation of matter. Radioactive materials seemed to simply disappear into nothing and this seemed to call into question the entire theory of matter. (They had not yet discovered Einstein's radical reformulation of Newton's principle of the conservation of matter - that matter and energy and interchangeable and the new principle is the conservation of matter-energy.)

Lenin reacted against this tendency by noting, quite independently of Einstein, who had already developed the physics three years earlier, that the new developments in physics do not warrant a turn toward mysticism and away from science, but rather they demand a new dialectic which would embrace both matter and energy. Lenin noted of Mach that he "has raised the very important and useful question of a space of n dimensions as a conceivable space." He then took Mach to task for "failing to emphasize that only the three dimensions of space could be verified experimentally." (Kaku, p 68).

The physical interpretation of the fourth dimension finally begins in 1905 with Einstein's theory of special relativity. The outlines of this theory are well known. I just want to mention its significance for the beginning of the overthrow of the Newtonian world outlook. With the special theory of relativity, space and time now become tightly intertwined. They are no longer separable and absolute as they were in Newton's physics. This means that motion in space affects time and vice versa. We all know some of the paradoxical situation that emerge from this. There is for instance the case of the high school graduates, one of whom immediately after graduation, departs for trip to the outer planets in a rocket ship. The rocket ship is traveling close to the speed of light and eventually returns twenty Earth years later - just in time for his high school reunion. Everyone at the reunion has aged twenty years, they are heavier, have more lines on their face, the men have receding hair lines. Except our astronaut. He looks exactly the same as the day he left. The reason for this is that for him twenty years of time did not elapse. In fact just a few days had elapsed as far as he was concerned. Our astronaut's experience of time is no less real than the experience of his classmates. Both are equally real because time is not an absolute but is a function of motion in space.

Not satisfied with having overturned Newton's conception of absolute space and time, several years later, Einstein put the final nail in the coffin of Newtonian physics with his general theory of relativity. It is with general relativity that the Riemannian theory of 'n' dimensions is finally given a coherent physical explanation. He was able to unite the space-time continuum posited by the special theory with gravity and demonstrate, as Riemann had postulated, that the concept of forces acting at distance can be dispensed with. Gravity is a property of the nature of a curved space of four dimensions. And incidentally, the general theory of relativity provides the most powerful explanation of the all the ordinary phenomena that was analyzed by Aristotle at the dawn of the age of science. It is gravity, ultimately a property of the geometry of four dimensions, that explains why a ball falls toward the earth and a flame rises to the heavens. Summarizing, with the advent of both the special theory of relativity and the general theory of relativity, the Newtonian universe based on Euclidean geometry and forces acting on objects at a distance had the rug pulled out from it.

The physics of the 20th century was to offer many more surprises. The next one came with the discovery of quantum mechanics. This new branch of physics completely overthrew the traditional conceptions of the behavior of simple particles. In fact, one could no longer say if something was a particle or a wave. Nor could one determine exactly where any particular particle was at any one time, something that went completely counter to classical mechanics. Needless to say, the assumption that reality is made up of simple entities, atomic facts or sense data, also becomes untenable. That does not mean however that it suddenly stops playing any role. Philosophy today, as it id in the 17th century, lags behind the sciences. I should perhaps qualify that last statement by indicating that I am talking of the dominant philosophical trends today. There does exist a philosophy, sidelined and mostly ignored by scientists and philosophers, that is remarkably open to the new developments in science, and can in turn encourage the deepening of these developments. This is what I will address in my closing remarks.

Toward a New Synthesis

Throughout the 20th century, a new physics emerged, and is still in the process of emerging, that has supplanted the Newtonian physics just as surely as the scientific revolution of the 17th century supplanted the Aristotelian Ptolemaic view of the world. But the new discoveries in physics did not sit well either with philosophers who were searching for some principle of integration emerging from the new physics, or with physicists themselves. The problem was that after Einstein's brilliant synthesis of space-time and matter and energy, physics was unable to unify the various types of forces it had discovered under a single comprehensive theory. In particle physics especially, the problem became evident. For as more and more particles were being discovered by physicists working with atom smashers, there were several hundred at the last count, it seemed that science had degenerated into an incoherent classification of data whose internal symmetry and connection remained a total mystery. Eventually something known as the Standard model was developed to provide a coherent explanation of particle physics. The problem was that the standard model, while consistent with quantum mechanics, could not account for gravity, which was left to relativity theory. It was as if the world, the Whole of which science seeks a unified conception, had been irrevocably broken up into separate parts which had nothing to do with each other. Einstein himself felt this problem very keenly and prior to his death sought a solution through a unified field theory, a solution that eluded him.

It is in the last three decades that the possibility of unifying all the phenomena known by physics begins to emerge with the development of superstring theory. Some of its champions, notably Edward Witten of Princeton University, and Michio Kaku, (whose book Hyperspace I have liberally borrowed from in this last segment) are convinced that superstring theory may prove to be the holy grail that Einstein was seeking, the Theory of Everything. [Note by the way the incongruity of Chomsky's earlier statement, that the whole is not a real topic, at the very time when physicists are seriously considering the Theory of Everything].

How does superstring theory seek to unite the disparate areas of physics, particularly quantum mechanics and relativity theory? The mathematics is incredibly complicated and well beyond anything I can comprehend. But the basic idea is fairly simple. It is that the laws of physics are simplified, as Riemann and Einstein demonstrated, when extra dimensions are posited - suddenly anomalies have a simple explanation. Superstring theory today postulates a universe that was originally not just of 4 or 5 dimensions, but of 10 dimensions. It is able to encompass, purely from the properties of a 10 dimensional universe, the forces that lead to the creation of the universe itself. The 10 dimensional hyperspace is now the most accepted explanation for the Big Bang that started the ball rolling.

With the Big Bang, we come to a question that in one form or another has bedeviled philosophers, scientists, poets and painters since antiquity. And this is the question of origins. For the modern physicist the question is in the form of what was there before the Big Bang. The nearest anyone can articulate an answer to this question is that prior to the Big Bang we had a 10 dimensional universe, which with the Big Bang is split into a four dimensional universe and 6 dimensional universe. Of course, one could then go on and ask what was there before the 10 dimensional universe. I don't know if anyone can answer that one, or even if the question makes any sense. In the Aristotelian cosmology, the question of origin is settled very simply. The universe was set into motion (remember its natural state is to be at rest) when a first cause got everything going. This first cause, the Prime Mover, is itself uncaused, i.e. God. And you cannot ask what caused the first cause, because by definition it is the first cause and that is the end of it. Now the Roman poet Ovid also asked the Big Bang question and answered it in his own way. He asked, if woman begat man, then who begat the first woman. It's one of those paradoxes. Either there was a first woman or there was not. If there was, then where did she come from. If there was not, then how does woman originate? Michaelangelo faced the same question. When he drew the figure of God and Adam and Eve on the ceiling of the Sistine chapel, he did not give them a belly button. Does anyone know why? (Hint: The first of their kind, God, the first man and the first woman, do not need and cannot have an umbilical cord attached to them, for no one could have given birth to them.)

[I now know, having finally visited the Sistine Chapel this past summer, that I was completely wrong about Michelangelo. The artist was in fact a member in good standing of the pro-belly-button party, and not, as I thought for some reason, of the anti-belly button brigade. My humble apologies for this mistake. A.S. 2/23/2002]

These riddles are unsolveable so long as we accept rigid oppositions. So long as we think history begins with some kind of origin and there is no history before it. An origin is simply a moment of becoming, a moment of being and not being, although if it is the Big Bang, it is obviously a very significant moment. [1]

We have now arrived at what I think is characteristic of science throughout all the phases of its history, and that is the necessity to find a principle of order, to unify, to explain the particular through the universal principle of organization. This was the founding principle, the charter so to speak that originally motivated Aristotle, and from which contemporary philosophy, in the form of its dominant mode of empiricism, has strayed. It is the reason for having a First Philosophy alongside the particular sciences. By discovering the mathematical relations between bodies in motion, the 17th century revolution in science brings the heavens and the earth together under the rubric of a common set of laws of motion. The principle of uniting all of knowledge within a single whole has been articulated throughout history and has sometimes taken very strange and contradictory forms. In the 17th and 18th century one of the expressions of this impulse was the work of those who compiled the first encyclopedias, the first attempt to bring together all of knowledge. The principle of organization of these early attempts to unify all areas of knowledge however tended to be somewhat arbitrary. One of most curious of

[1] I should point out that the physicist Stephen Hawking is of the opinion that it is meaningless to speak of time prior to the Big Bang.

these principles of organization that I have come across was the medieval encyclopedia produced by Domenico Bandini whose gigantic 'Fons memorabilium universi' was divided into 5 parts in honor of the 5 wounds of Christ.

At least there was here an attempt to find a unifying principle. The philosophy of rigid opposition that emerges from the 17th century on becomes an obstacle to conceptualizing new and higher unities. It becomes the work of those who go against the stream, who are able to overcome the rigid dichotomies of current orthodoxies, people such as Riemann and Einstein, Schrodinger and Heisenberg and the pioneers of superstring theory, it is such people who are able to overcome the conceptual limits of their time.

The need to unify knowledge grows out of the profound conviction that reality is a whole and is not composed of incommensurable parts. There are of course parts, but the parts are themselves interconnected to higher level wholes and they themselves constitute wholes in their own right. This is not an empty whole in other words. The empty whole is the kind of pseudo "wholism" that passes for philosophy among New Age mystics, who go about saying such wisdom as "We are part of the One". We are talking about an articulated Whole. It is what Hegel called the concrete Universal or the Absolute. The Absolute in this sense is not a transcendent deity, a view that has often mistakenly been ascribed to Hegel, but the totality of the determinations of reality whose discovery is the work of the individual sciences and whose ultimate organization is the work of logic and philosophy. It is the reason for having a First Philosophy alongside the particular sciences. By discovering the mathematical relations between bodies in motion, the 17th century revolution in science made a big stride forward in articulating the whole. But Newtonian physics and Euclidean geometry was but a historically limited version of the truth as we have since come to appreciate. Its truth has been taken up and both preserved and transcended with the scientific revolution of the last century. We are now possibly at the threshold of the elaboration of a new synthesis of the universe. Do we have the conceptual tools to digest it? [2]

[2] In this connection it is apropos to cite the remarks of the physicist Stephen Hawking, who is one of the few contemporary physicists to recognize the need for a reunification of science and philosophy.

"Up to now, most scientists have been too occupied with the development of new theories that describe what the universe is to ask the question why. On the other hand, the people whose business it is to ask the question why, the philosophers, have not been able to keep up with the advance of scientific theories. In the eighteenth century, philosophers considered the whole of human knowledge, including science, to be their field and discussed questions such as: Did the universe have a beginning? However, in the nineteenth and twentieth centuries, science became too technical and mathematical for the philosophers, or anyone else except a few specialists. Philosophers reduced the scope of their inquiries so much that Wittgenstein, the most famous philosopher of this century, said, 'The sole remaining task for philosophy is the analysis of language.' What a comedown from the great tradition of philosophy from Aristotle to Kant."
Stephen Hawking, A Brief History of Time: From the Big Bang to Black Holes, Bantam Books, p. 174-175.
Hawking correctly defines the problem of philosophers who eschew science. The other side of the problem of course is that of the scientist who "rejects" philosophy.

The Dialectic of Nature

As I have indicated, the scientific revolution gave birth not only to empiricism and mechanistic philosophies, but was also the impetus to the development of the great tradition of German idealism, culminating in Hegel. And from Hegel, via the Left Hegelians and Feuerbach, we get to Marx and his elaboration of a materialist dialectic. And it is especially to Marx's collaborator Engels, that we are indebted for the first explicit attempt to formulate a dialectics of nature, a coherent systematic philosophy that is able to account for, and encourage the development of the sciences as a living process. But some of you may object, I am using the word dialectic, and have been using it for some time, without elaborating what it is or how it is to be employed. This is in a sense true - but if you consider the matter a little more deeply, you may realize that I have in fact been articulating a dialectic or at least attempting to do so, throughout my talk. I started with science and philosophy as it was originally posited, the Aristotelian view of the world. I then tried to examine the negation of this world outlook in the scientific and philosophical revolution of the 17th century. I then conclude with the supercession of Newtonian physics and with it the outmoded philosophy of empiricism - into the new physics defined by relativity theory, quantum theory and the physics of 10 dimensions - the negation of the negation.

Each of the major phases of the history of science that I have described represents a qualitative leap in the language of Engels and the dialectic. At the same time, I hope to have shown that these qualitative leaps were prepared over a long period by a gradual accumulation of new and incongruous (according to the old theories) data.

I have also tried to illustrate how the movement of progress is always contradictory, that in fact the opposites interpenetrate. Thus, we have the truth of the new physics of the 17th century announce itself in the garb of the old philosophy of Platonism. Or else we have the bizarre adventures of the fourth dimension in the parlor halls of a London séance, eventually leading to the greatest revolution in scientific thought man has ever witnessed. Movement is existent contradiction. [3]

In the Dialectics of Nature, Engels mentions three laws of the dialectic. They are:

1. The law of the transformation of quantity into quality and vice versa.
2. The law of the interpenetration of opposites.

[3] This contradictory historical movement, in which the new content is emerging from within an old form, recalls something Marx wrote in the 18th Bruimaire of Louis Bonaparte,
"The tradition of all the dead generations weighs like a nightmare on the brain of the living. And just when they seem engaged in revolutionizing themselves and things, in creating something that has never yet existed, precisely in such periods of revolutionary crisis they anxiously conjure up the spirits of the past to their service and borrow from them names, battle cries and costumes in order to present the new scene of world history in this time-honoured disguise and this borrowed language."

3. The law of the negation of the negation.

This talk has tried to show how all three of these laws are expressed through a survey of the historical development of physical science and its philosophical articulation. At the same time, I wish to provide a caution against attempting to use Engels' formulation of the basic laws of the dialectic as some kind of a magic key. Nor should one think that Engels formulation somehow exhausts the laws of dialectic. They are simply a very brief and high-level summary. Much more can and ought to be said. A great deal of damage was done in the past by so-called Marxists, who reading Engels popular presentation, and it should be pointed out unpublished and unfinished account of the dialectic, went about seeking to find examples of these laws in the sciences. Thus for several decades, Soviet philosophers of science, thinking they were carrying on the work of Engels, did little more than repeat some of the by now stale examples Engels provided of developments in chemistry and physics. Little attempt was made to look at science in a fresh way, to both understand and guide the deepening of the unifying principles of science. The Stalinists of course completely distorted Engels and Marx's dialectic and turned it into a lifeless dogma. At one point, relativity theory was under attack in the Soviet Union because of its supposed threat to materialism. [4] In the West on the other hand, the work of Engels was mostly ignored, and considered at best a remnant of a romantic philosophy of nature. This was but another consequence of the triumph of the empiricist viewpoint in the English-speaking world. Engels' hypothesis of the dialectical structure of nature could not be taken seriously because it was so at odds with the ingrained and hidden metaphysical assumptions of the empiricist outlook. This illustrates a point once raised by Marx, that the dialectic, when stripped of its mystical shell, is thoroughly revolutionary and an embarrassment to all the forces embracing the status quo. [5]

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[4] Stalinism also inherited and debased still further the prejudicial attitude against philosophy that we have seen expressed in philosophers such as Hobbes. In some of the Stalinist regimes in Eastern Europe it was not even possible to take a degree in philosophy on the grounds that Marxism completed philosophy! This anti-philosophic stance had no trouble coexisting with an official state-sponsored philosophy – one that turned Marxism upside down from a philosophy of human liberation to an apologia for bureaucratic rule.

[5] Elaboration of this issue would lead us into a discussion of the harmful effects of an anti-dialectical outlook when applied to biology and the social sciences. The reactionary consequences of positivism in this area is a huge topic that has been discussed on many occasions. What has been rarely discussed however, has been the inimical impact that an empiricist philosophy has on the science of physics. My purpose has been to begin such a discussion. We may add that it was also the fate of Hegel's Philosophy of Nature, like that of Engels later materialist elaboration of a philosophy of nature, to be consigned to the museum of historical antiquities. This work, which comprises a third of Hegel's Encyclopedia, and therefore a key component of his system, is considered today a curious piece of antique and arcane Romanticism. Even staunch Hegelians, ready to defend the Philosophy of Spirit, were embarrassed by Hegel's Philosophy of Nature. Apparently, a dialectics of nature, even in its Hegelian form, remains beyond the pale. The reason for

It is my belief that dialectical philosophy is indispensable for the comprehension and encouragement of science. This does not of course give the philosopher a blank check to create science out of whole cloth. The dialectician who does not know science will never generate a scientific principle. On the other hand, the scientist who is not aware of the dialectic, will inevitably run into insuperable obstacles. The dialectical union of science and philosophy must be restored.

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this reaction by Hegelians is however a topic for another occasion.

Afterward: Suggestion Reading

1. Michio Kaku, Hyperspace, available in German as **Im Hyperraum. Eine Reise durch Zeittunnel und Paralleluniversen.**
   von Michio Kaku. If you can only read one book then I would recommend this one. It is a lucid explanation in laymen's terms of the impact of extra dimensions on contemporary physics. Many of the examples cited in my talk were borrowed from this work. The author is not just a popularizer of science but is a working physicist and one of the founders of string theory.
2. Stephen Hawking, A Brief History of Time, available in German as **Eine kurze Geschichte der Zeit.** von Stephen W. Hawking – Broschiert. Popular presentation of many of the issues in contemporary cosmology from one of the leading theoreticians of our time.
3. Frederich Engels, Dialectics of Nature. Engels classic statement on the role of dialectical philosophy in the natural sciences. This is widely available in German.
4. Alexandre Koyre, Gallilean Studies . This work is out of print in both German and English, but many related essays by Koyre on Galileo and the revolution in science in the 17th century are available in both languages. He also wrote the classic work, From the Closed World to the Infinite Universe (**Von der geschlossenen Welt zum unendlichen Universum)** which traces the rise and triumph of the new cosmology.