W O R D S   O F   E M P T I N E S S

A CENTRIST VIEW OF SCIENCE AND REALITY

B. Alan Wallace

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Faculty Advisor:

Arthur G. Zajonc, Assoc. Prof. of Physics

Readers:

Arthur G. Zajonc, Assoc. Prof. of Physics

Robert A. Thurman, Prof. of Religion

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While making the initial translation of the Sanskrit text, I used the version edited by P.L. Vaidya (Buddhist Sanskrit Text Series). I also consulted the Tibetan translation published by the Tibetan Cultural Printing Press in Dharamsala, India, and Stephen Batchelor's English translation of the text. While working on later drafts, I consulted Michael Sweet's translation in his 1977 doctoral dissertation in Buddhist Studies at the Univ. of Wisconsin, entitled Śāntideva and the Mādhyamika: The Prajñāpāramitā-Pariccheda of the Bodhicaryāvatāra.

To the best of my knowledge, this is the first attempt to apply the mode of philosophical inquiry of the Buddhist Centrist view to the foundations of physics. Initial works of this nature are bound to be flawed, and I only hope that the shortcomings of my efforts stimulate others to elucidate this rich subject with greater mastery and insight.

INTRODUCTION

This text is chiefly of a philosophical nature, having the aim of investigating the foundations of modern physics. Thus, its discussions of certain scientific and historical issues are primarily for the sake of providing specific examples and context for the philosophical questions that are raised.

We shall begin with an examination of one of the most intriguing and important subjects in contemporary physics, namely, the nature of the vacuum. Quantum field theory indicates that the vacuum is filled with "virtual energy" from which particles may emerge; and cosmologists speculate that the entire universe may have originated from a fluctuation of this vacuum energy. This text begins by looking into modern theories of the vacuum and its energy. It then proceeds to examine a theoretical prediction and its experimental verification that allegedly provide evidence for the existence of the vacuum energy.

As we further investigate this subject, we find that the same theoretical prediction is offered by several conceptually incompatible theories of the vacuum. Thus, the implications of the experimental verification of that prediction become questionable. Historically, if a single theory uniquely yields a prediction that is subsequently confirmed, that theory is generally regarded as "true." Now we encounter the situation--actually not uncommon in modern physics--in which multiple theories equally account for the same phenomena. How then are we to choose which one among them is "truest" of physical reality?

The subject of the vacuum is intimately related to three physical concepts: space, energy and the ether. Thus, if we are to gain a clear understanding of the vacuum, we must certainly know what is meant by these three terms. We have already noted that contemporary physicists, presented with the same body of empirical evidence, are of different minds concerning the nature of the vacuum. This may encourage us to discover whether there has historically been similar diversity of opinion among physicists concerning the nature of space, energy and the ether. Moreover, if such divergence of views has been present during the rise of science, we may ask whether this dissention originates simply from scientific considerations, or from philosophical and theological predilections as well. With these questions in mind, we shall therefore review the development of these concepts from the time of Galileo to the present century.

Following this historical excursion, we shall pursue the broader topic of the philosophical foundations of physics, posing the question: In what way do physical theories relate to reality? The prevalent view among physicists is that their science represents objective, physical reality as it exists in its own right, independent of human experience. This metaphysical stance is commonly known as "realism," and we shall examine its tenets and assumptions in the context of both of classical and modern physics. Another view of physical theory is that it simply correlates observed data in a coherent way, without making any statement about physical reality as it exists independent of experiment. There are a variety of such views, but for simplicity's sake they are generally referred to in this text as "instrumentalism." This alternative to realism is then analyzed.

The foregoing investigation raises a number of problems in the foundations of physics that are not adequately resolved by either realism or instrumentalism. The alternative presented here is called the "centrist view," which seeks to avoid the untenable philosophical extremes of the preceding two views of physics. The centrist view declares that the universe that human beings inhabit, experience and conceive of in our physical theories does not exist independently of the human mind. We dwell in a participatory universe that is as inextricably related to us as we are to it. This view avoids the extreme of idealism, for it denies that mind is any more real than the physical world; and it rejects the materialist extreme of asserting that mind is nothing more than a quality of matter. Both mind and matter are regarded by the centrist view as dependently related events.

This fresh approach to the foundations of physics addresses an even broader problem concerning science and the humanities. Since the Copernican Revolution, an ever-broadening gulf has arisen in Western civilization between science and religion. This disintegration of world view has contributed to the present crisis of humankind, in which we have won great knowledge and power over nature, but with no comparable growth of wisdom and moral responsibility. Alfred North Whitehead writes that philosophy "attains its chief importance by fusing...religion and science into one rational scheme of thought."[1] This present work can hardly claim to have accomplished such a fusion, but it does present one attempt to establish greater understanding between these two ways of viewing the world.

The discussion of the centrist view presented here is actually a contemporary application of the "Centrist View" of Buddhist philosophy, known as "Madhyamika." Regarded by many as the pinnacle of Buddhist philosophical insight, it addresses a number of the same issues that are presently discussed by physicists concerned with the implications of modern quantum mechanics. Although Buddhist contemplatives and Western physicists approach these problems from very

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[1] Process and Reality, A.N. Whitehead (The Free Press, N.Y., 1978) p. 15.

different perspectives, their respective philosophies may mutually benefit from sharing each others' insights. The philosopher of science F.S.C. Northrop writes in this regard:

> It is the coming together of this new philosophy of physics with the respective philosophies of culture of mankind that is the major event in today's and tomorrow's world.[2]

Following our contemporary application of the Centrist View to the foundations of physics, this volume concludes with a translation from the Sanskrit of a portion of a classic, eighth-century treatise that deals with this view in its native context. The translation is of the ninth chapter of a work entitled A Guide to the Bodhisattva Way of Life[3] by the Indian scholar and contemplative Shantideva.[4] This chapter, named "Transcendent Wisdom," sets forth the Centrist View of Buddhist philosophy in the context of other

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[2]Introduction to Physics and Philosophy: The Revolution in Modern Science, Werner Heisenberg (Harper & Row, Publishers, N.Y., 1962) p. 26.

[3]Sanskrit: Bodhisattvacaryāvatāra

[4]Madhyamika philosophy traces back to the Buddha's own teachings. This philosophical view was first systematized by the Indian sage Nagarjuna several centuries after the Buddha's death. Thus, Shantideva, living in the eighth century of the Christian era, was dealing with a philosophical system that had already been studied and practiced for over a millennium in the rich intellectual and spiritual environment of classical India.

Buddhist and non-Buddhist views. From a Western perspective it is philosophical in content; yet it has a definite religious tone to it, and it also demonstrates empirical means for testing its conclusions.

The translation of this text has been made primarily on the basis of a commentary in classical Tibetan by the 14th-century Tibetan master Tsongkhapa.[5] However, reference has also been made to the Sanskrit commentary by Prajñākaramati[6] and to another Tibetan commentary by a major student of Tsongkhapa.[7] The text is accompanied by a translation from spoken Tibetan of an oral commentary presented by H.H. the Dalai Lama, Tenzin Gyatso, during the summer of 1979 in Rikon, Switzerland.[8]

As mentioned previously, the central theme of this work is of a philosophical nature. The initial discussion of the vacuum avoids mathematical arguments, which are included in the appendices. Nevertheless, this section of the text may

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[5]Tibetan: sPyod 'jug shes rab le'u'i tikka blo gsal ba. The chapter titles and other headings within Book II are based chiefly on Tsongkhapa's outline in the above commentary.

[6]Sanskrit: Pañjikā

[7]sPyod 'jug rnam bshad rgyal sras 'jug ngogs by rGyal tshab dar ma rin chen.

[8]This commentary on Shantideva's entire text was presented before a mixed audience of close to a thousand Tibetans, Europeans and Americans. We may surmise that it was directed primarily to the Tibetans, for it was delivered in the Tibetan language, without any translation. I attended that series of discourses and have here translated the commentary to Shantideva's ninth chapter from recordings.

be somewhat challenging to readers without any background in physics. If there are those who feel bogged down in either this or the following historical discussion, they are encouraged to proceed directly to Part III, which concerns the heart of the text. Such readers may then be drawn to return to Parts I and II simply for reference purposes.

The present rifts between science and the humanities and the lack of understanding between Eastern and Western ways of viewing the world contribute to the tensions that beset humankind today. The challenge before us is to strive towards the formation of a "planetary culture," which draws from the unique insights and achievements of the world's civilizations. The present work has been carried out with the aspiration to contribute to such worldwide understanding, for the benefit of all concerned.

B O O K   I:

D E M Y S T I F Y I N G   T H E   F O U N D A T I O N S   O F   P H Y S I C S

P A R T   O N E:

T H E   N A T U R E   O F   T H E   V A C U U M

CHAPTER ONE:

THE MYSTERY OF EMPTY SPACE

Since the time of Thales, dwelling on the eastern shores of the Mediterranean some 2500 years ago, the Western mind has pondered the nature of the physical universe, posing the question: What is the fundamental substance of which the world is made? A great variety of responses to this inquiry have been made. Thales speculated that the basic stuff of the universe is water, while modern physics, probing the structure of atomic nuclei, hypothesizes that quarks may be the fundamental building blocks of the material world. Research continues as scientists develop yet more powerful tools for exploring more minute elements of matter; and present hypotheses are in no way considered to be final or incontrovertible.

A complementary subject of inquiry concerns not the nature of matter, but the arena in which physical objects arise, move about, interact, and pass from existence. This is the subject of space, and then more specifically the vacuum. Western concepts of space have for the past two millennia been deeply influenced by the thought of Aristotle, but again the ensuing variety of views on this subject have been plentiful and diverse. In his treatise entitled Categories Aristotle depicts space as the sum total of all places occupied by bodies, and the term "place" (topos) designates that part of space whose limits coincide with the limits of the occupying body. In his Physics he develops only a theory of place, or positions in space, while rejecting the concept of general space. According to this view, place is different from its movable contents--for a thing can leave its place--and its qualities exert an active influence on the elements. Nevertheless, while place is independent of the distribution of mass, its qualities are dependent on the existence of matter.

The above theory in Aristotle's Physics was most influential for the further development of space theories. It swiftly prompts the question: What is the nature of the vacuum, or space empty of matter? The earlier atomists, such as Leucippus and Democritus, originated the idea of a void existing in its own right, absolute and independent of contained things. Aristotle sharply refuted this view, declaring that the concept of the vacuum is nonsense. What is empty, he argued, is nothing, and what is nothing has no existence. Moreover, if a vacuum were to exist, it would provide no resistance, and consequently all forces would produce infinite speeds. Thus, from the era of Greek antiquity, the concept of the vacuum has implied to some thinkers the problem of infinite divergences.

Aristotle's views concerning space and the vacuum strongly influenced medieval thought as well as later theories set forth by such men as Descartes and Leibniz. Descartes claimed that space exists only by virtue of a continuous distribution of matter; and Leibniz, denying that space exists where there is no matter, maintained that it is not an independent reality. Newton's view's on this subject as articulated in his Mathematical Principles of Natural Philosophy sharply differ from the above. For him, absolute space is a logical and ontological necessity; it exists in its own nature, without relation to anything external. He thus adopted a view tracing back to the pre-Aristotelian atomists, and as his system of mechanics spread, so did his concept of absolute space.

Kant, a great critic of scientific theorizing, departed from both streams of thought concerning space in his declaration that there is no object in the external world called "space." It is not an object of perception, but a mode of perceiving objects, and it exists independent of the bodies apparently contained in it. As such, space is an appropriate subject of examination for transcendental philosophy, and not for physics. Although this view was hailed as one of the greatest achievements in contemporary philosophy, it was, understandably enough, received rather coolly by most physicists. Nineteenth-century physics continued to assert that all objects of the external world are endowed with spatial extension, and the geometric character of this extension is--contrary to Kant's belief--purely a matter of experience.

Einstein's special theory of relativity, presented in 1905, was the first major, scientific challenge to Newton's assumption of absolute space. In proposing that the speed of light signals traversing space is invariant with respect to different inertial reference frames, Einstein refuted the classical notion of space as the absolute medium in reference to which absolute motion occurs. The invariance of this maximum speed--which turns out to be the speed of light--led to the realization that space, while not possessing an absolute frame of reference, is more than mere nothingness. It would seem to possess physical structure.

According to this theory, space by itself and time by itself are peculiar to each observer, but the four-dimensional world of spacetime, containing only events and worldlines, is an independent reality. All decompositions of spacetime into the separate components of space and of time are equally real, and hence the name "relativity." General relativity takes the further step of proposing an intimate relationship between spacetime curvature and matter. Many contemporary physicists now believe, on the basis of the theory of relativity, that spacetime is objectively real and that it does not exist by virtue of matter alone.

During the opening decades of this century, another physical theory was developed which challenged a number of classical concepts, including that of the vacuum. This was, of course, the quantum theory. Briefly stated, one feature of quantum theory indicates that although a region of space can in principle be emptied of ordinary matter, this vacuum is neither empty nor featureless. Rather, it has a complex structure that can in no way be eliminated. To appreciate the startling new insights of quantum mechanics into this subject, and the fundamental questions it raises, it would be worthwhile to glance at some of the earlier, classical notions of the vacuum.

A practical definition of the vacuum may be stated as: whatever is left in a region of space when it has been emptied of everything that can possibly be removed from it by experimental means.[1] During the seventeenth and eighteenth centuries, frequent experiments were performed with the vacuum, which was regarded as space free of matter. In the following century, it was found that space free of matter may still contain thermal radiation, which, like a

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[1] "The Classical Vacuum" Timothy Boyer, Scientific American, Aug., 1985, p. 70.

gas, can be said to respond to compression with a rise in pressure and temperature. Consequently, such an enclosed region of space may, under compression, exert a force on its containing walls. Thermal radiation is comprised of randomly fluctuating electromagnetic fields, and its character is reflected in its temperature.

Thus, a region of space utterly devoid of matter may still contain energy if thermal radiation is present; and this further suggests that a true vacuum must not only be free of matter but also have a temperature of absolute zero. This was an insight of nineteenth-century thermodynamic theory transcending that of the matter-oriented classical mechanics of the preceding two centuries.

Thermal radiation in a cavity presented an apparently insurmountable anomaly in the closing years of the last century. Experimental measurements of the power as radiated out as light of a small hole in a cavity revealed that the emitted energy approaches zero for vibrational high frequencies of the light. Classical thermodynamics, however, predicted that the energy should approach infinity as the frequencies approached infinity. This discrepancy was known as the <u>ultraviolet catastrophe</u>--another problem entailing an infinite divergence.

In 1900, Max Planck proposed a radical means of eliminating this discrepancy, and in so doing, laid the foundation for quantum theory. Simply stated, he postulated that the energy that is absorbed and emitted by the atoms of the cavity walls is quantized; i.e. the absorbtion and emission of thermal radiation takes place not continuously--as assumed by classical electromagnetism--but by jumps of a discrete amount, or quantum of energy. In this theory Planck regarded the quantum property as belonging essentially to the interaction between radiation (of the cavity) and matter (of the cavity walls). He still regarded free radiation as consisting of continuous electromagnetic waves, in accordance with classical electromagnetic theory. It was Einstein who, in 1905, suggested that even free radiant energy exists in discrete quanta, later to be called _photons_.[2] Planck's original theory predicted that at a temperature of absolute zero the energy of the cavity would vanish. Thus, containing no matter or energy, that region of space would be a true vacuum. However, in 1911, he modified this theory, and the revised version predicted the existence of a residual energy even at absolute zero degrees of temperature. This came to be known as the _zero-point energy_ of the vacuum.[3] Although Planck himself, as well as his colleagues, swiftly discarded the specific conceptual

[2]This term was not introduced until 1926 by G.N. Lewis.

[3]The term "zero-point" refers not to temperature but to the energy equation for a simple harmonic oscillator, $E=(n + \frac{1}{2})hf$, in which the quantum number n equals zero.

grounds for this revised theory, his mathematical prediction of a residual energy in the vacuum remains.[4]

If such a zero-point energy does exist, it would seem to be an inherent property of space; and since there is no known means of removing it, once matter and other forms of radiant energy have been eliminated, it would indeed be the energy of the vacuum.

The existence of zero-point energy for simple harmonic oscillators is firmly established in quantum mechanics. Experiments with solid crystals provide one of many bodies of evidence for its presence. The atoms of a crystal are bound together in a lattice structure by electromagnetic forces, as if they were held in place by invisible springs. Whenever one of the atoms is jostled, e.g. by thermal radiation, it oscillates. X-ray diffraction pictures show fuzzy diffraction maxima associated with the motion of the atoms resulting from thermal radiation. As the temperature of the crystal is decreased, one expects the maxima to sharpen up; and if there were no zero-point energy of those atomic oscillators, the maxima should sharpen up indefinitely. Thus, at absolute zero of temperature, their width would be reduced to zero. Experiments show, however, that a

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[4]In Planck's 1911 theory he proposed that the emission of radiation always takes place discontinuously in quanta, whereas absorption is a continuous process which takes place according to the laws of classical theory. In 1914, he abandoned that theory in favor of the idea that both emission and absorption of energy by the oscillators in the cavity are continuous; but he discarded that theory a year later.

certain degree of fuzziness in the maxima persists even at temperatures very close to absolute zero. This suggests that a simple harmonic oscillator retains a minimum quantity of energy even in its ground state--a conclusion theoretically predicted by the Heisenberg uncertainty principle.

There is also ample experimental evidence to indicate that the vacuum has a structure. According to modern quantum electrodynamics, the vacuum is permeated by fluctuating electromagnetic fields. The average energy of those fields is generally considered to be zero,[5] but they have non-zero fluctuations, which affect the position of an electron. Using the classical picture of an electron orbiting about a nucleus, the fluctuations of the energy of the vacuum would cause it to jiggle about, thereby affecting its energy level. The resultant difference in energy is known as the Lamb shift.[6] The theoretical calculation of this effect agrees closely with experimental results; but it is interesting to note that once again infinite divergences occur in the calculations--for both low and high frequencies--and physical effects need to be invoked to

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[5]This subject is examined more closely in the following chapter.

[6]For a more detailed and technical discussion of this effect, see I.J.R. Aitchison's paper "Nothing's plenty: The vacuum in modern quantum field theory" in Contemporary Physics, Vol. 26, No. 4, 1985, pp.347-350.

dispel them. The Lamb shift is regarded as one illustration of the "reality" of vacuum field fluctuations.

According to modern quantum field theory, the electromagnetic and matter vacuums contain arbitrary numbers of virtual photons and other particles. As in the case of the energy of the system of fields in the vacuum, they do not exist "on the average"; but for very brief moments they may have a sort of "virtual existence" allowed again by the energy-time uncertainty relation. Real particles introduced into the vacuum interact with the vacuum fluctuations (or virtual quanta), to the extent that in relativistic quantum field theory the concept of a "single particle" actually breaks down. Over sufficiently short times it will be inseparable, in principle, from attendant fluctuations of the matter vacuum. Virtual particles that carry charge are always formed in pairs, each member holding the opposite charge to that of its partner. If high energy photons are emitted into the vacuum, electron-positron pairs can be "knocked out" of the vacuum, thus drawing them from "virtual" to "actual" existence.

There is even serious speculation that the entire universe may have originated from the vacuum. The energy-time uncertainty relation allows an arbitrarily small fluctuation in energy to occur for an arbitrarily long period of time. Thus, if the net energy of the entire universe were approximately zero, an arbitrarily long-lived universe might fluctuate into existence out of the vacuum. Such a zero net energy is not absurd, for the positive matter-energy density might be cancelled by the negative gravitational potential energy existing in the cosmos. In fact, rough order-of-magnitude estimates of the observed mass density of the universe suggest that the two quantities are remarkably close. For the time being, however, this theory remains highly speculative.

To sum up, the "classical vacuum" state, free of all matter and fluctuating fields, is not physically realizable. Neither matter nor energy can be relied upon to be absolutely non-existent in any region of space. Thus, both relativity theory and quantum theory, for different reasons and in different ways, unequivocally declare that empty space, or the vacuum, has structure. Its precise nature is still being explored and many problems remain, but all of modern physics asserts that it is not a featureless, quiescent, property-less void. Empty space is clearly, yet is some sense mysteriously, other than nothing.

CHAPTER TWO:

THE ENERGY OF THE VACUUM

In the preceding chapter brief reference was made to the zero-point energy of the vacuum, but this was followed by a discussion of the Lamb shift and pair formation of particles entailing the assumption that the energy of the vacuum is zero. This inconsistency reflects a certain ambiguity on the subject that persists in contemporary physics. Even if the energy of the vacuum is considered to be zero, it is still agreed that the vacuum contains electromagnetic and matter waves that fluctuate around zero and thereby affect actual matter and energy states.

Furthermore, it is not entirely clear that even the average energy of the vacuum, apart from field fluctuations, is in fact zero. The mathematical calculations of quantum field theory, taken at face value, suggest that an inherent residual energy of the vacuum remains even at absolute zero of temperature. The present discussion will not examine those calculations but offer rather a qualitative sense of the justification for that conclusion.[1]

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[1] A mathematical treatment of this subject is given in Appendix I.

A simple harmonic oscillator is one entailing linear restoring forces, i.e. the force acting on an object is proportional to its distance from its point of equilibrium. An example that approximates such an oscillator is a pendulum when its oscillations are quite small. It has a frequency, which is the rate at which it swings back and forth, and an amplitude, which corresponds to the magnitude of its oscillations. A simple harmonic oscillator is also approximated by an object attached to a spring and oscillating at low amplitude, and by the atoms in a crystal lattice jiggling about under the constraint of approximately linear electromagnetic forces. In classical mechanics the energy of a simple harmonic oscillator can be reduced to zero simply by bringing it to equilibrium: That is, stop its movement. When that occurs, both the position of the oscillator and its momentum are precisely defined, the latter being zero.

In quantum mechanics, however, the more precisely the position is defined, the greater the uncertainty in the momentum. This is a direct consequence of the Heisenberg uncertainty principle. Thus, the momentum of an oscillating atom, for instance, can never be reduced to zero; i.e. the atom can never be perfectly still. It must remain at least slightly on the move; otherwise, the uncertainty in its position would blow up to infinity. This is too high a price to pay for immobility. In its lowest energy state an atom maintains an average momentum of zero, due to cancellation of positive and negative values for the momentum. However, since the kinetic energy of an oscillating atom is proportional to the square of its momentum, that lowest energy state must be greater than zero, for such cancellation no longer occurs. The lowest possible energy of a simple harmonic oscillator is known as its zero-point energy. Its existence is firmly established both theoretically and experimentally.

How does this zero-point energy of a simple harmonic oscillator relate to the energy of the vacuum? Let us imagine a vacuum enclosed within a cube, with the walls as its boundary conditions. Within this region is a system of electromagnetic fields that oscillate between the boundary walls, which we will assume to be perfect conductors. The existence of such fields is widely acknowledged in contemporary physics, on both theoretical and experimental grounds. Given those boundary conditions, it is possible to identify normal modes. The field associated with a single mode of the cavity oscillates at a well-defined frequency and possesses a specific amplitude (and polarization). There are a definite number of such modes, each with its own frequency, and each mode acts as a simple harmonic oscillator.

Regarding each mode as a simple harmonic oscillator, it follows that each one has an associated energy value. In quantum theory that energy is quantized, and each quantum is proportional to the frequency associated with that mode. The total energy in that single mode will be just the sum of the individual quantum contributions. The total energy of the electromagnetic fields within the enclosed vacuum can be written as the sum of the mode energies. The elementary quanta of energy, or excitation, of the electromagnetic fields are called photons. The ground state of such a field system contains no photons and is known as the electromagnetic vacuum. However, despite the fact that no photons are present, the ground state of all the normal modes of the system, each acting as a simple harmonic oscillator, does not entail zero energy. This point follows from the preceding discussion.

Now the total energy of the vacuum enclosed within an imaginary cube is the sum of the energies of all its normal modes, each one associated with a mode frequency. In three dimensions the modes are actually specified fully by frequency, direction and polarization. Now there is a lower limit to those frequencies, determined by the boundary conditions of the cube, but how high do those frequencies go? We have no justification for positing an upper limit to them, and the energy density of the electromagnetic vacuum approaches infinity as the mode frequencies approach infinity. Thus, the zero-point energy of the electromagnetic vacuum is calculated to be infinite.

Recall that a similar infinite divergence, referred to as the ultraviolet catastrophe, was the anomaly that led Max Planck to lay the foundation of quantum mechanics. The problem he was concerned with was thermal radiation in a cavity, and it was deemed a catastrophe since the theoretical infinite divergence of energy was contradicted by experimental evidence. The present divergence concerns the zero-point energy of the vacuum, and it is not flatly contradicted by empirical evidence.

If the above theoretical conclusion concerning the energy of the vacuum is taken at face value, it must transform our concept of space in the most radical way. The mathematical calculations indicate that the energy density of the vacuum is infinite. More graphically stated: The energy inherent in one cubic centimeter of empty space is greater than the energy of all the matter in the known universe. This energy density is present throughout all of space, including regions where matter and other forms of energy are present. It is not confined to regions of pure vacuum. Seen in this light, the zero-point energy of the vacuum appears as a vast omnipresent ocean of infinite energy; and all other forms of energy--thermal, gravitational, etc.--appear as the thinnest of films upon the surface of this fathomless sea. Couched in such language, one may even begin to wonder whether this may have religious implications: Is this infinite energy a facet of God's omnipresence? And it stimulates a number of philosophical questions, such as: Might this ground-state energy of space be the fundamental, unified source of all physical and cognitive phenomena?

Most physicists, however, tend to avoid such speculations concerning this infinite divergence. In fact, the majority of advanced texts on quantum electrodynamics skirt the issue. An exception is E.A. Power's Introductory Quantum Electrodynamics. Here the author points out that despite the infinite divergence of the zero-point energy of the vacuum, it can still be regarded as a constant; and since physics is generally concerned with only the energy differences, the energy of the vacuum can simply be set at zero.[2] Mathematically this adjustment from infinity to zero is brought about by techniques of "regularization" or "renormalization." Some of these methods appear to a have a physical justification, while others seem to be mere ad hoc measures for dispensing with unwanted and embarrassing infinities. By such techniques, the average energy of the vacuum is returned to zero, such that on the surface there seems to be an agreement with the naive classical view that the vacuum contains nothing. Note, however, that this renormalization does not dispense with the fluctuating

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[2] Introductory Quantum Electrodynamics, E.A. Power (American Elsevier Pub. Co., Inc., N.Y., 1964) p. 32.

electromagnetic and matter fields of the vacuum, nor their manifold effects, such as pair formation of particles.

Furthermore, as E.A. Power points out, there is one compelling branch of modern physics that is concerned not merely with the differences in energy states, but with their absolute values.[3] This branch is the general theory of relativity. This theory prohibits physically unjustifiable, ad hoc methods of redefining energy values. Gravitational energy in particular is an absolute quantity in nature, and its value must not be arbitrarily altered.

Thus, once again we are faced with the question: Is the infinite zero-point energy of the vacuum physically real? Or is it simply a mathematical anomaly devoid of physical relevance, a mere artifact of an abstract theory? As an analogy we may look to the subject of tachyons, particles that travel at speeds only greater than the speed of light. Their existence is suggested by the negative solution of a quadratic equation in special relativity. A physics of tachyons can be formulated which is consistent with Einstein's theory, and for awhile, considerable effort was directed to the search for empirical verification of their existence. Despite all efforts, no such evidence was forthcoming, so tachyons are now usually discarded as physically unreal.

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[3] ibid., p 33.

Paul Dirac, one of the most chief architects of modern quantum theory, adopts such a view with regard to the infinite energy of the vacuum. In an article entitled "Quantum Electrodynamics without Dead Wood"[4] he declares that this energy is purely of a mathematical nature. Moreover, the infinite divergence can be avoided altogether, he writes, if one always works with the Heisenberg representation of the theory rather than that of Schrödinger. Although those two representations are usually regarded as equivalent, he used this point to illustrate that this is not so. In his own words: "the Heisenberg picture is a good picture, the Schrödinger picture is a bad picture, and the two pictures are not equivalent."[5]

A major factor that is generally understood to distinguish physics from metaphysics is that the former is concerned only with theories that lend themselves to empirical verification or refutation. If no experimental evidence can be found to test a theory, practicing physicists are bound to lose interest. Thus, the infinite energy of the vacuum may be disregarded on the grounds that it is unobservable. No instrument has been invented that is able to measure infinite energy. But before we abandon the subject altogether, we may ask: Is there any indirect evidence in support of this zero-point energy. In their

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[4] Physical Review 139, B 684 (1965).

[5] ibid. p. 685. The italics are Dirac's.

textbook entitled Quantum Field Theory Claude Itzykson and Jean-Bernard Zuber declare that variations in that energy can be measured, specifically in the experimental confirmation of a theoretical prediction known as the Casimir effect.[6]

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[6] Quantum Field Theory, Claude Itzykson and Jean-Bernard Zuber (McGraw-Hill Book Co., N.Y. 1980) p. 139.

CHAPTER THREE:

THE CASIMIR EFFECT IN THEORY AND PRACTICE

In the spring of 1948, the theoretical physicist H.B.G. Casimir presented a short paper entitled "On the attraction between two perfectly conducting plates,"[1] in which he devised an ingenious means for experimentally coming to terms with the zero-point energy of the vacuum. Reasserting that the infinite divergence of electromagnetic energy even in the vacuum cannot be avoided for a single cavity, he discovered a way of calculating a finite difference between the energies of two cavities.

Casimir's paper is highly mathematical and it deals with an idealization that can be approximated in the laboratory: Consider a cubic cavity bounded by perfectly conducting walls.[2] Now let one of those walls be moved very close and parallel to the opposite face of the cavity. The standard calculations of quantum electrodynamics indicate that the electromagnetic energy within this narrow corridor of a vacuum is infinite. Likewise, when the wall is moved further away from the opposite boundary, the infinite

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[1] Proc. kon. Ned. Akad. Wetenschap 51, (1948) 793.

[2] For a detailed examination of Casimir's paper, see Appendix II.

divergence remains, and Casimir deems both divergences as "devoid of physical meaning." The rationale for this view is presumably that infinite energies cannot be measured.

Having set up equations for the energies of the two cavities, Casimir grounds this thought experiment in physical reality by pointing out that real plates enclosing a vacuum do not act as perfect reflectors for all frequencies of electromagnetic fields. Ultraviolet and gamma radiation, for example, would pass through the walls as if they were not there. This fact provides a physical justification for introducing a cut-off point to the mode frequencies for the cavity. The divergences are thereby banished, but one is still left, mathematically, with vacuum energies of the two cavities. It turns out then that there is a finite difference between the potential energies of the two cavities: The larger cavity, understandably enough, contains a greater energy.

It is a well-known fact in physics that a difference of potential energy requires the presence of a force; or, more, exactly, the force equals the negative of the gradient of that potential energy. For example, there is a difference in potential energy between that of a compressed spring and one that is in equilibrium, suggesting the presence of a spring force. Likewise, the gravitational potential energy of a baseball in flight is greater than when it has fallen to the ground. This difference is associated with gravitational force.

In the present case, there is a difference in potential energy in the two situations when two opposing walls of the cavity are close together and far apart. This implies that there must be a force acting on those plates, a force not due to gravity or electric charges on the plates; rather, it is a zero-point force derived from the electromagnetic energy inherent in the vacuum.

Casimir calculated the direction and magnitude of this force. He found it to be attractive, and the force per unit area of the plates is proportional to Planck's constant and to the speed of light, and it is inversely proportional to the fourth power of the distance between the plates. This force is very weak and since it drops off very rapidly as the plates are separated, it can be detected only when they are roughly one-half micron (five ten-millionths of a meter) apart. While acknowledging that the effect of this zero-point force is small, Casimir suggests that an experimental confirmation may be feasible.

Casimir's proposal is lucid, its mathematical calculations are simple and elegant, and its physical assumptions appear reasonable. But in order for this so-called Casimir effect to make its imprint upon physics, its prediction of a zero-point force must be experimentally confirmed. Having followed Casimir's mathematical derivation, Itzykson and Zuber declare that this "very tiny force has been demonstrated by Sparnaay (1958), who was able to observe both its magnitude and dependence on the interplate distance!"[3] I.J.R. Aitchison reports that "Sparnaay, using chromium and chromium steel plates...was able to demonstrate its existence."[4] And Timothy H. Boyer, in his paper entitled "The Classical Vacuum," reports:

> In 1958 the Dutch physicist M.J. Sparnaay carried out a series of experiments based on Casimir's proposal and found that the force did not approach zero when the thermal radiation was reduced to low intensity. Instead there was a residual attractive force that would persist even at absolute zero.[5]

He goes on to point out that this residual force is inversely proportional to the fourth power of the separation of the plates, and it is due to the vacuum fields now

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[3] Quantum Field Theory, C. Itzykson and J. Zuber (McGraw-Hill Book Co., N.Y., 1980) p. 141.

[4] "Nothing's plenty: The vacuum in modern quantum field theory," I.J.R, Aitchison, Contemporary Physics 26 4, 1985, p. 343.

[5] "The Classical Vacuum," T. Boyer, Scientific American, Aug., 1985, p. 74.

referred to as classical electromagnetic zero-point radiation.

With such unequivocal accounts of Sparnaay's achievement, reported by esteemed and responsible physicists, we may feel safe in assuming their validity and in moving on to ponder the implications of this experimental confirmation of the Casimir effect. However, for our own satisfaction, it behooves us first to examine Sparnaay's own account of his experimental work and his conclusions.

Sparnaay presents his work in a paper entitled "Measurements of attractive forces between flat plates"[6]; and in the introductory abstract he states that in his experiments concerning attractive forces between flat metal plates, the "observed attractions do not contradict Casimir's theoretical prediction."[7] The cautious wording of this conclusion is worth noting. In his description of the experimental apparatus, the types of plates used, and the experimental technique, Sparnaay demonstrates his care and precision as an experimental physicist. Due to the great subtlety of the predicted force, he had to go to great lengths to prepare the system so that this force could be detected. The quality of the vacuum in which the force

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[6] M.J. Sparnaay, Physica, 24, (1958), 751-764.

[7] Sparnaay's paper is analyzed in greater detail in Appendix III.

manifested itself, however, was relatively poor. He reports that in the vacuum chamber a pressure not lower than one-hundredth of a millimeter of mercury was obtained. By modern standards, a pressure of one-millionth of a millimeter is regarded as a high vacuum, and with present-day technology this can be surpassed by several orders of magnitude.

Nowhere in Sparnaay's account is there any reference to thermal radiation, nor did his experiment entail any cooling of the (low-grade) vacuum, let alone reducing its temperature to near absolute zero. Reviewing Boyer's reference to the experiment, we may wonder if he ever examined Sparnaay's paper; for he describes an experimental procedure and results that never took place.

When two flat metal plates are brought very close together (about 0.1 micron) in a vacuum, a force acting on them is predicted, for which the explanation is very different than for the zero-point force. This other force, known as the London-Van der Waals force, is due to the static polarizability of the atoms in the two plates. Simply stated, this has to do with the polarization of the electrons and nuclei of the atoms in the plates, which gives rise to a minute attractice force that is inversely proportional to the third power of the distance separating the plates. Thus, in order to confirm experimentally the presence of the zero-point force, one seeks data that would decisively indicate a force inversely proportional to the fourth power, and not to the third power, of the distance between the plates.

In this series of experiments Sparnaay used plates composed of three types of metal. When he used two aluminum plates, he found that a repulsive force occurred between them in contradiction to the attractive force predicted by Casimir. He frankly admits that the origin of such repulsion is not clear, but speculates that it may be due to the presence of a thin oxide layer on the plates. Using chromium plates, he obtained only two data points, each with rather large error margins. Such sparse results are insufficient for drawing unequivocal conclusions about the force. Finally, when chromium steel plates were used, he obtained eight data points, each with large error margins, indicating an attractive force between the plates.

Sparnaay does not present a table of the numerical data from these experiments; rather he draws a graph of the force versus the distance as predicted by Casimir and shows how his data approximate that curve. Five of the eight data points for the chromium steel plates include (within their error bars) the curve predicted by Casimir. Overall, it looks like the experimental data correspond reasonably well to the theoretical prediction; and, as mentioned above, Sparnaay concluded that his results "do not contradict Casimir's theoretical prediction."

If one closely examines his data for the chromium steel plates, one may be startled to find that they indicate the presence of a force inversely proportional to the third power of the distance between the plates; and the margins for error do not include the possibility of an inverse fourth-power force.[8] Moreover, the magnitude of the observed force is consistent with that predicted for the London-Van der Waals force. In short, Sparnaay's data give a clear confirmation of the magnitude and direction of the London-Van der Waals force, including the fact that it is an inverse third-power force. The margins for error in those data preclude the presence of an inverse fourth-power force. Thus, his experiments in no way demonstrate the existence of a zero-point force as predicted by Casimir. If anything, they would appear to refute its existence.

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[8] Such an analysis is presented in Appendix III.

CHAPTER FOUR:

INTERPRETING THE CASIMIR EFFECT

As we have seen, the standard textbook account of the experimental confirmation of the Casimir effect, as well as historical references to it in scientific journals tend to be overly simplified, if not simply inaccurate.[1] E.A. Power cites three experimental papers prior to Sparnaay's experiments which he claims demonstrate the Casimir Effect,[2] (using non-metal plates); but an examination of those papers available in English indicates results hardly more conclusive than those of Sparnaay.[3]

The Casimir effect should again be put to experimental test using the more advanced technology that has been developed since Sparnaay's work. Far greater precision could be obtained, and it would be of interest to whether an observed force between conducting plates in a vacuum

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[1]This fact gradually became apparent during my research. I have been unable to find any more conclusive demonstration of the zero-point force with the use of metal plates, nor does either Professor Casimir or Professor Sparnaay know of any such experiments after Sparnaay's work. This was acknowledged by both men in personal correspondence to my inquiries.

[2]Introductory Quantum Electrodynamics, E.A. Power (American Elsevier Pub. Co., Inc., N.Y., 1964) p. 34.

[3]The paper by B.V. Deryagin and I.I. Abrikosava written in Russian was not examined by the author. The abstract in English makes no claim of demonstrating the Casimir effect.

persists even at temperatures approaching absolute zero. That is, it would be informative to conduct the experiment that Boyer imagined had already been performed, and to see whether the conclusions that he reported are born out in the laboratory.

Recall that, according to Itzykson and Zuber, an experimental confirmation of the Casimir effect implies a measurement of a variation of the infinite energy of the electromagnetic vacuum. Aitchison points out that the zero-point energy of the vacuum is far too securely founded simply to ignore it, and he states that no completely satisfactory resolution for the "difficulty" of its infinite divergence exists. Thus, an empirical demonstration of the force predicted by Casimir would seem to be of great interest in terms of testing the physical reality of the infinite energy of the vacuum. Is this not, after all, how physics has made its tremendous advances over the past four centuries?: (1) A physical theory is formulated with the use of mathematical calculations, (2) a specific quantitative prediction is made on the basis of that more general theory and (3) experiments or observations are performed that confirm the specific prediction, thereby empirically demonstrating the validity of the initial theory.

Imagine that an experiment is performed that clearly indicates an inverse fourth-power force between two conducting plates in a vacuum at a temperature close to absolute zero. Assume, too, that its magnitude and direction correspond closely to Casimir's predictions. Does this prove the existence of a zero-point force whose origin is the infinite energy inherent in the electromagnetic vacuum? In the opening lines of his aforementioned paper, Casimir remarks that calculations for a similar problem were previously derived by taking the London-Van der Waals forces as a starting point and altering them to account for retardation effects. Calculations for a retarded London-Van der Waals force take into consideration the effects of special relativity.[4] Those formulas involve the static polarizability of the atoms in the conducting plates, and there is explicit reference to electric charge; whereas the formulas for the zero-point force do not include polarizability or charge. The point is that the calculations for the effects of retarded London-Van der Waals forces and for the effects of the zero-point force yield exactly the same prediction. Thus, an empirical verification of that prediction equally confirms both theories, which are conceptually quite different.[5]

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[4] Such calculations were first done by H.G.B. Casimir and D. Polder, Phys. Rev. 73, (1948) 360.

[5] In fact, there is experimental confirmation of both the unretarded and retarded the London-van der Waals potentials. See "Measurements of retarded van der Waals' Forces," W. Black, J.G.V. de Jongh, J. Th. G. Overbeek and M.J. Sparnaay, Faraday Soc. Trans. 56, (1960) 1579; and "Surface forces: Direct measurement of normal and retarded van der Waals Forces," D.

Which of the two theories then corresponds to physical reality? Perhaps the retarded London-Van der Waals force and the zero-point force between the plates are in fact the same force. However, the theoretical identity of these two has never been demonstrated, and the concepts relating to the two forces certainly appear quite separate, if not unrelated. If both forces are real and distinct, would this not suggest that they should be additive? There is no evidence at present to suggest that. Thus, the problem remains: Even if experiment conforms to the predicted attractive force, two vying theories equally claim to explain the origin and nature of that force; and the experimental data by themselves do not decide between them.

This ambiguity concerning the Casimir effect is generally ignored in references to it and its experimental confirmation. Focussing now on the zero-point force alone, we may ask: If a means is found to demonstrate its physical reality, as distinct from the retarded London-Van der Waals force, does this indirectly confirm the existence of the infinite energy of the vacuum? In an article entitled

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Tabor and R.H.S. Winterton, Nature 219 Sept. 14, 1968, p. 1120. Those experiments did not employ metal plates, as suggested by Casimir, nor do use his theory of zero-point energy. Rather, they use a more comprehensive theory of this force, in which the formulas of Casimir and Polder are contained as limiting cases of a formula develped by E.M. Lifshitz [Sov Physics JETP 2 (1956) 73]. More recent confirmation of these forces has been gained using a very different experimental approach by E.S. Sabisky and C.H. Anderson [Phys. Rev. A 7, 2 (1973) 790].

"Regularisation schemes for the Casimir effect,"[6] M. Reuter and W. Dittrich repeat the claim that the physical reality of the zero-point force was confirmed by the experimental observations of Sparnaay. They also regard this as an observable consequence of the divergence of the energy of the vacuum. However, the theme of their paper is then to apply regularization schemes to this effect, whereby that divergent energy is "normalized," i.e. reduced to zero. They go on to derive three independent regularization schemes, all of which yield the same prediction, viz. the attractive, inverse fourth-power force exactly as predicted by Casimir. All of those derivations start from the notion of a vacuum bearing a structure due to zero-point oscillations; and their purpose is to reduce the calculated divergence of the vacuum energy to a mean value of zero, while still accounting for the Casimir effect.

Thus, an empirical confirmation of the Casimir effect may be used equally as grounds for believing in the physical reality of infinite zero-point energy of the vacuum and of an average zero energy of the vacuum. In both cases the vacuum is assumed to have a structure. Can we therefore state that the physical reality of a structure to the vacuum is an unambiguous conclusion of the experimental demonstration of the Casimir effect? Unfortunately not, for

[6] European Journal of Physics 6, (1985), pp. 33-40.

in 1975, J. Schwinger[7] showed a way of accounting for the Casimir effect within the context of the so-called "source theory,"[8] which assumes the vacuum to be without structure. The mathematical results that he obtains with that theory are identical with those predicted by Casimir!

Casimir's prediction concerning a zero-point force between conducting plates in a vacuum is made within the conceptual and mathematical context of quantum electrodynamics. As mentioned above, this theory regards the electromagnetic vacuum as the ground state of the system. As such, the vacuum is a state--not a substance--with no quanta of excitation. Thus, no photons, i.e. elementary quanta of excitation of the electromagnetic field, are present in the vacuum. Although the physical significance of the Casimir effect is subject to a diversity of interpretations within the context of quantum electrodynamics, we may at least conclude that it confirms the physical reality of the vacuum as it is conceived in that theory. However, Timothy Boyer's development of a theory of stochastic electrodynamics brings even that conclusion into question as well.

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[7] Lett. Math. Phys 1, (1975), 43.

[8] Particles, Sources and Fields, J. Schwinger (Addison-Wesley, Reading, Mass., 1973)

Recall that Max Planck laid the foundation for modern quantum theory in response to a problem involving thermal radiation in a cavity.[9] The relevant entropy-energy formulas of Wein and of Rayleigh and Jeans, which were derived in the context of classical thermodynamics, were contradictory, and they presented no solution to the so-called ultraviolet catastrophe. Planck's formula expressing his famous radiation law arose as a natural modification of the connection between the entropy and energy of thermal radiation, which formed an interpolation of the above two formulas. As Boyer points out:

> Only after noting the success of this modification did Planck return to try to find a theoretical justification for the modification. He found an explanation in the notion of discrete units of energy, the notion of quanta.[10]

Planck's radiation formula conformed with experimental evidence, and he saw that it could be justified by modifying the classical calculation of thermodynamic probability by the use of quanta. Since 1969, Boyer has written a series

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[9] For a historical account of the development of his theory, see E.T. Whittaker's A History of the Theories of Aether and Electricity, Modern Theories 1900-1926 (Philosophical Library, N.Y., 1954) Ch. 3.

[10] "Classical Statistical Thermodynamics and Electromagnetic Zero-Point Radiation" Phys. Rev. 186, 5 (1969) 1313.

of technical papers demonstrating that the introduction of the notion of quanta is quite unnecessary. Planck initially introduced the concept of quanta into physical theory to account for certain experimental results involving thermal radiation; and in the ensuing decades, as quantum mechanics has developed into an extremely successful theory, the physical reality of quanta has widely come to be taken for granted. Boyer challenges this assumption by resolving the initial problem in thermal radiation without introducing quanta.

The ultraviolet catastrophe indicated the failure of energy equipartition in classical statistical mechanics, and today this failure is ascribed to quantum effects. However, Boyer has shown that within the context of classical theory, the traditional arguments for energy equipartition are erroneous.[11] Those arguments, he claims, "fail to recognize that all particles considered by traditional equilibrium thermodynamics must have electromagnetic interactions and must radiate on striking the container walls. Thus, for example, the traditional ideal gas fails to exist in principle for particles of finite mass."[12] By including the ideas of interaction with the electromagnetic field,

[11] T.H. Boyer, Phys. Rev. 186, (1969), 1304.

[12] "Third Law of Thermodynamics and Electromagnetic Zero-Point Radiation," T.H. Boyer, Phys. Rev.D 1, 6, (1970), p. 1529.

classical theory leads naturally to the idea of random fluctuating radiation in the universe.

The main new concept in Boyer's work is the existence, at absolute zero of temperature, of a classical, fluctuating, electromagnetic background radiation, which produces the same effects as the ground state of the radiation field in quantum electrodynamics. Thus, he speaks of classical, rather than quantum, electromagnetic zero-point energy. One of the fundamental differences between the two theories is that while the fluctuations of the vacuum energy in quantum electrodynamics have only "virtual" existence, the fluctuations of the classical zero-point radiation are regarded as "real."

One of the fascinating results of Boyer's theory is that by incorporating the above radiation into classical statistical physics, he has been able to derive Planck's blackbody spectrum (relating to thermal radiation with a cavity). The presence of this vacuum energy causes a zero-point energy for all particles which have electromagnetic interactions, thereby necessitating a reformulation of thermodynamics of low temperatures. Boyer shows that this reformulation leads directly to the the third law of thermodynamics, which is widely regarded as an expression of the quantum nature of thermodynamic systems. In short, he arrives at the conclusion that "the idea of quanta forms a subterfuge for what is a natural part of a theory of classical thermodynamics including electromagnetism."[13] To date, Boyer has presented four classical derivations of Planck's spectrum, all incorporating classical electromagnetic zero-point radiation.[14] In each one he replaces the notion of quanta with a theory of fluctuations of this radiation.

The notion of the universe being pervaded by a medium of classical radiation is bound to stir memories of an ether. The concept of an all-pervading ether was especially popular in the nineteenth century, and it entailed the assumption that the ether provides an absolutely stationary inertial frame in reference to which absolute motion takes place. Einstein's special theory of relativity banished that assumption, and ever since then students have been taught that the ether is a fiction based upon false assumptions of classical physics. T.W. Marshall, like Boyer after him, postulates that the zero-temperature spectrum of radiation is observable and that it is responsible for quantum effects.[15] Specifically, he claims that the

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[13] T.H. Boyer, Phys. Rev. 186, 5, (1969), p. 1313.

[14] T.H. Boyer, Phys. Rev. D 29, 6, (1984), 1096. This paper is particularly noteworthy, for it derives the blackbody radiation spectrum from the equivalence principle that is a fundamental tenet of general relativity theory. See also the article "Is there a quantum equivalence principle?" by P. Candelas and D.W. Sciama, Phys. Rev.D 27, 8, (1983), 1715. For a less technical discussion of this subject see the final section of Boyer's Scientific American article cited previously.

[15] T.W. Marshall, Proc. Camb. Phil. Soc. 61, (1965), 537.

measurement of Planck's constant constitutes an observation of the zero-point spectrum. He then proceeds to set up this random, pure radiation field in a relativistically invariant manner. That is, he introduces a new concept of a pervasive radiation field--bearing a clear resemblance to the ether--that does satisfy the demands of special relativity.

Boyer examines this subject in his own work.[16] A requirement of special relativity is that the vacuum should not define any special velocity through space, i.e. it should look the same to any observers traveling at different constant velocities. A system that meets this requirement is said to be invariant with respect to Lorentz transformation. To meet that condition, the spectrum of zero-point radiation must have quite specific properties. In particular, the intensity of the radiation must be proportional to the cube of its frequency. Such a spectrum is the same for all unaccelerated observers, regardless of their velocity; and it is the only one that has this property. Moreover, this quality of the classical vacuum energy bears a direct relationship to the force predicted in the Casimir effect. A theoretical calculation based on this cubic spectrum predicts a force corresponding precisely to Casimir's prediction, viz. one that is proportional to the area of the plates and inversely proportional to the fourth

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[16] Scientific American, Aug., 1985, p. 70-78; T.H. Boyer, Phys. Rev. 182, (1969), 1374.

power of their separation. No other spectrum supports that prediction.

The statement that the zero-point spectrum is described by a cubic curve gives no indication of the magnitude of the intensity of the radiation. The magnitude depends on a constant whose value cannot be calculated theoretically. Boyer claims that Sparnaay's measurement of the force in the Casimir effect, after some algebraic manipulation, allows the value of that constant to be determined from experiment.[17] It turns out to equal one-half of Planck's constant, appearing now not as an element of quantum theory, but in a purely classical context.

Once again we are faced with the question: If the Casimir effect is experimentally confirmed, what knowledge of physical reality would this yield? Both the zero-point energy of quantum electrodynamics and of Boyer's classical vacuum would be equally verified, but the two concepts are fundamentally incompatible. The former theory is a branch of quantum mechanics, which asserts the existence of quanta as its most fundamental tenet. Boyer rejects that notion and introduces a classical, fluctuating radiation that accounts for so-called quantum effects. Not only is the quantum hypothesis unnecessary for deriving Planck's radiation law, it is now seen to be expendable in terms of

[17]In view of the previous analysis of Sparnaay's experiment, it may be more accurate to state that an unequivocal experimental confirmation of the Casimir effect would yield that constant.

explaining other experimental evidence that contributed to the development of quantum theory. Early in this century, Einstein proposed a number of situations that he thought could be most naturally explained in terms of quanta. Boyer reviews those examples and shows how they can be reinterpreted, without quanta, in terms of classical electromagnetic zero-point radiation.[18] In fact, it is no secret among those well-versed in the foundations of quantum mechanics that the original justifications for the necessary physical reality of quanta are now seen as quite tenuous.

Would a confirmation of the Casimir effect enlighten us as to the density of the zero-point energy? Quantum electrodynamics suggests first that it is infinite and then, upon normalization, reduces it to zero. The classical interpretation pursued by Marshall and Boyer also yields an infinite field energy, now as a natural consequence of assuming Maxwell's equations. Marshall regards this as a central difficulty of the classical theory, whereas Boyer sidesteps the issue, pointing out that modern physics has developed methods for dealing with unsettling infinities. Whether those methods are any more physically justifiable in his theory than in quantum mechanics is a moot question.

As we have followed a rather detailed inquiry into the nature of the vacuum and its zero-point energy, we have come

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[18] T.H. Boyer, Phys. Rev. 186, 5, (1969), 1304.

across a diversity of mutually incompatible theories that all account for the Casimir effect.[19] Reports of the experimental confirmation of this effect appear to be inaccurate and generally unreflective as to its physical implications. But even in the event of a clear experimental verification, what insight would this yield as to the physical nature of the vacuum?

As mentioned above, physics textbooks leave students with the impression that understanding of the physical world progresses in the straightforward manner outlined previously: (1) A general, encompassing theory is formulated; (2) it is found to yield a quantitative prediction for a specific experiment or observation; and (3) if the prediction is empirically confirmed, this indicates that the concepts in the initial theory correspond to physical realities. What textbooks and popular scientific articles tend to omit is the fact that such an empirical confirmation may equally support multiple competing and incompatible theories.

As we have found in confronting such a diversity, the psychological response may be other than the one textbooks and popular articles wish to encourage. Upon initially addressing our minds to a subject such as the vacuum, we may

[19] There are yet other theories relating to the vacuum that have not been mentioned, such as supersymmetry, which states that the energy of the vacuum is zero, and another cosmological theory that suggests that it is finite.

be fascinated and eagerly anticipate the experiment that will verify the physically true theory. We may feel like travelers setting out on a clear-cut path through a dense forest. Eagerly we look forward to emerging out to a promontory that will give us a broad, clear view, far out over the surrounding countryside. But as we tread deeper into this forest, we encounter more and more forks in the path, and each one is marked with a sign declaring "Promontory, this way." Are all the signs correct, or was a malicious prankster at work? Does only one path lead to the promontory that we long to reach, or might there be multiple promontories offering a diversity of views? Or are all the paths dead ends leading to no promontories, but merely giving us the opportunity to exercise as we wander in the dark?

Upon confronting a diversity of theories that equally account for the same body of experimental evidence and that yield identical predictions, we may become disheartened and lose interest. Or we may assume that only one of those theories (or an unformulated one) represents physical reality. This latter attitude encourages us patiently to identify the one true path by a gradual process of elimination; but it also entails the assumption that the choice will be narrowed down; i.e. that new competing options will not crop up as quickly as we eliminate old ones.

A third response to this problem of diversity is to step back from the methods of physics and to reflect on the nature of the scientific mode of inquiry. Thus, acknowledging this problem may lead us to a more philosophical inquiry rather than proper scientific research. The authors of physics textbooks and popular scientific reports do not seem keen on cultivating such a response. In fact, it is not uncommon to encounter among physicists an open contempt for indulging one's interests in historical and philosophical reflection. A central theme to be developed in the present work is that in the absence of such reflection, scientific research may be meaningless at best and possibly catastrophic to the society that devotes itself to such blind probing into physical reality.

In the foregoing investigation of the nature of the vacuum, three terms have been used that are crucial to understanding this phenomenon: space, energy and the ether.[20] If the vacuum is comprised of a region of space containing fluctuations of energy and if it may be regarded as an ether in the sense of existing as a pervasive medium with a physical structure, the meaning of those three terms

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[20] It is worth noting that Dirac, too, has revived the notion of the ether in a manner consistent with both quantum mechanics and relativity theory. He, too, encounters the problem of infinite divergence in the vacuum, which he regards as a theoretical idealization bearing no physical reality. He thus concludes that the perfect vacuum is an idealized state, not attainable in practice. Aristotle would presumably have commended him on his insight. For an account of Dirac's theory, see his article "Is there an ether?" Nature 168, (1951), 906.

should be examined closely. It is worthwhile, for example, to consider the question of the energy density of the vacuum only if one has a reasonable clear understanding of energy itself. Thus, before moving on to the broader topic of the philosophical foundations of physics, let us conclude our discussion of the vacuum with a review of the development of these three concepts as they have been used in the history of physics.

PART II:

CLASSICAL CONCEPTS OF SPACE, ENERGY AND THE ETHER

INTRODUCTION

The subject of this section, as indicated by its title, is so broad and encompassing that it could easily fill several volumes of historical research. Since a comprehensive treatment of this threefold topic is clearly beyond the scope of the present discussion, it will deal only with the major thinkers in physics and the more influential concepts of space, energy and the ether that they formulated. We shall begin with the theories of Isaac Newton, the founder of classical mechanics, and conclude with those of Albert Einstein, who retained many classical physical assumptions while making monumental contributions to the breakthroughs of modern physics.

In addition to the physical concepts themselves, we shall make special note of the non-scientific influences that led to their formulation and general acceptance. Physics textbooks and contemporary physicists themselves frequently exhibit an impatience with philosophical, let alone religious, concerns with their science. This attitude may be expressed roughly as follows: Above all it was science that lifted European civilization from the murky waters of philosophical speculation and religious superstition that dominated the Middle Ages. The hard facts of physics in particular, as the exemplar of a quantitative, empirically based science, have revealed to Western civilization an ever clearer and more comprehensive vision of the universe; and it is modern science, based upon physics, that sets us apart from other societies. The scientific method is the one true way to explore the nature of reality, and its undisputable success is due in large part to its abandoning the shackles of philosophical bias and religious dogma. Thus, science should be held pure, unpolluted by the vagaries of metaphysical and theological thought, which are at best useless and are at times invidious. As we shall see in the following discussion, such an ideal of "pure science" is actually a pure fiction arising from a naive misconception of the history of science.

Another popular belief at least implicitly promoted by textbooks concerns the development of physical theories as scientific knowledge has progressed. According to this view, scientific theories--unlike philosophical and religious doctrines--compel the community of scientists as a whole to accept or reject them by means of the straightforward test of empirical verifiability. Thus, physics moved as a united front, embracing Newtonian mechanics in the seventeenth century, refining and extending this science in the eighteenth, adding thermodynamics and electromagnetism in the nineteenth, and moving on to the greater heights of relativity and quantum theory in the twentieth century. Although a diversity of incompatible theories may be proposed, only those that fit reality the closest survive; and their superiority is undeniable, for those theories are tested in the unprejudiced light of empirical data. Nature herself sifts out unfit theories, for they are crushed underfoot by the hard, cold facts of experience. The following examination of the development of three major physical concepts should make it clear that this belief, too, is a simplistic fallacy.

CHAPTER FIVE:

CONCEPTS OF SPACE AND THE ETHER AT THE BIRTH OF CLASSICAL PHYSICS

Isaac Newton set forth not only the mathematical principles of classical mechanics, but defended a metaphysical foundation for it which he regarded as indispensable. Although his famous statement "*Hypotheses non fingo*" (I do not feign hypotheses) is sometimes cited as an indication of his general unwillingness to speculate upon the reality behind observable phenomena, he was in fact deeply concerned with this matter. Moreover, he made the above statement specifically with regard to the cause of gravity, not to metaphysical questions as a whole; and, as we shall see, he was eventually willing to speculate upon the mechanism of gravity as well.

Possibly the most outstanding case of Newton feigning a metaphysical hypothesis is found in his assertion of absolute space and time. In this discussion we will be concerned with the former concept only. His views on the nature of space, as propounded in his *Mathematical Principles of Natural Philosophy,* are stated as follows:

> Absolute space, in its own nature, without relation to anything external, remains always similar and immovable. Relative space is some movable dimension or measure of the absolute spaces; which our senses determine by its position to bodies;...because the parts of space cannot be seen, or distinguished from one another by our senses, therefore in their stead we use sensible measures of them...instead of absolute places and motions, we use relative ones, and that without any inconvenience in common affairs; but in philosophical disquisitions, we ought to abstract from our senses, and consider things themselves, distinct from what are only sensible measures of them.[1]

Influences on Newton's concept of space can be traced back to Greek thought of antiquity and include the speculations of philosophers, theologians, mystics and scientists.[2] From Patritius, Campanella and Gassendi he adopted the concept of infinite, homogeneous and isotropic

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[1] Sir Isaac Newton's Mathematical Principles of natural philosophy and his System of the world. A revision of Mott's translation, ed. F. Cajori (Univ. of California Press, Berkeley, 1934) p. 6 & 8.

[2] cf. Concepts of Space: The History of Theories of Space in Physics, Max Jammer (Harvard Univ. Press, Cambridge, Mass., 1954) ch. 1-3.

space, and he regarded absolute space as a logical and ontological necessity. Newton did feel a disinclination to feign hypotheses and a desire to adhere to his methodological rule of admitting no more causes of natural things than are both true and sufficient to explain their appearances. Yet he believed there was a justification for absolute space, which is hidden from the senses.

Newton believed that he had experimentally confirmed the existence of absolute space on the basis of absolute motion. This, he felt, is illustrated in the "revolving pail experiment." Here a pail of water is suspended from a twisted rope. When the pail is first released and begins to revolve, it moves relative to the water, whose surface is level. Gradually, as the water begins to rotate, its surface becomes paraboloidal, until eventually the circular motion of the water "catches up" with that of the pail. At this point, when the water and pail are no longer in relative motion, the pail is suddenly stopped. Once again the two are in relative motion, but in contrast to the initial relative motion, the surface of the water is now paraboloidal.

Apart from the reversal of directions (which should have no effect on the dynamical result), the relative motion of the two is identical, while the effect on the surface of the water is not. If all motion were relative, reasoned Newton, the effect on the water should be the same in those two instances. Since the dynamical effect on the water is different, rotation is absolute. Real forces create absolute motion, and such motion produces the appearance of centrifugal forces. It is apparent then that Newton's concept of absolute space was an indispensable basis for his first law of motion. The existence of absolute motion is crucial, and he defines it as "the translation of a body from one absolute space to another,"; whereas relative motion is "the translation from one relative place into another."[3]

Newton's concept of relative spaces corresponds to our notion of coordinate systems. It is worth noting, as an aside, that he regarded geometry not as a hypothetical system of propositions, but as a branch of mechanics. Geometry was widely regarded, during Newton's time, as the exemplar of what natural, "certain" knowledge should be like. There were those, however, who were skeptical of mechanics insofar as it laid claim to certainty. By linking geometry and mechanics as he did, Newton was saying that anyone who placed greater trust in geometry than in mechanics was ignorant of the foundations of both.[4]

In addition to his concern with metaphysics, Newton was a devout Christian with a deep commitment to theological

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[3] Principles, p. 398.

[4] This point was brought to my attention by historian George Servos.

inquiry. Indeed, during the closing decades of his life he dedicated himself more to matters of theology than to physics.[5]

Newton's concept of space was an expression of his theology as well as his metaphysics and mechanics. His teacher Isaac Barrow held to a view of geometry in which space is the expression of divine omnipresence. As indicated in later editions of his Principles, toward the end of his life Newton identified absolute space with God, or with one of His attributes:

> He endures for ever, and is everywhere present; and by existing always and everywhere, he constitutes duration and space.[6]

He viewed space as a physical entity that is fundamentally different from material bodies. Whereas matter is a "derivative and incomplete entity," space, as an incorporeal physical entity which is independent of matter, has existed eternally. The existence of matter is contingent on God's will, and to attribute to it a "complete, absolute, independent reality" like space would "manifestly offer a path to Atheism."

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[5]cf. Never at Rest: A Biography of Isaac Newton, Richard S. Westfall (Cambridge Univ. Press, N.Y., 1980).

[6]ibid. p.544.

Newton's own conception of absolute space was not without its opponents. His great rival Gottfried Wilhelm von Leibniz objected that space is nothing but a system of relations, devoid of metaphysical or ontological existence. He draws a well-known analogy between space and a system of genealogical lines, in which a place is assigned to every person. From this analogy he reasons that to assert the existence of absolute space is like hypostatizing such a system of relations.

Leibniz, however, was unable to refute the existence of real, or absolute, motion, as apparently demonstrated in Newton's revolving pail experiment. He was thus forced to distinguish between absolute motion and relative change of place, while rejecting Newton's distinction between absolute and relative space. Leibniz declared that one body that is the immediate cause of change of place in another is in absolute motion, but this is a dynamical process which is completely unrelated to space as such. Christian Huygens took a more radical stand:

> Most people suppose that the true motion of a body consists of its being transferred from a certain fixed place in the universe. This is wrong; for if space is unlimited in all directions, what then is the definition of immobility of a place?...It is therefore impossible to state that a body is at

rest in infinite space, or that it moves therein; rest and motion are therefore only relative.[7]

Whereas Leibniz recognized his inability to refute Newton's empirical evidence for absolute motion, Huygens did deny that implication. Indeed, neither the views of Leibniz nor Huygens concerning space gained a wide following; and the development of the science of mechanics over the next two centuries seemed to provide ample confirmation of Newton's hypothesis.

The concept of space has a direct bearing on the mechanism of gravity. According to Leibniz, gravity is reducible to the contiguous action of the fluid medium of an ether, not by a force acting at a distance through absolute space. Newton was not content with his theory of action-at-a-distance, and he eventually posited the existence of a mediating ether as well. In his Opticks he speculated that the ether is composed of exceedingly small particles. A medium more rare and elastic than air, it is less able to resist the motions of projectiles and far more able to press upon gross bodies by its innate tendency to expand. Particles of Newton's ether are separated by void space and they act on each other by repulsive forces. The natural tendency of this medium to expand enables it to press upon

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[7] D.J. Korteweg & J.A. Schrouten, Jahresbericht der Deutschen Mathematiken-Vereinigung 29, 136 (1920). Cited in Concepts of Space, p. 122.

gross bodies and hence cause planets to approach or recede. Obviously, the problem of action-at-a-distance was not really solved with the introduction of such an ether, for the particles of which it is composed still act on one another at a distance, while separated by absolutely empty space.

In Newton's view the ether lacks inertia--a fundamental quality of matter--and it acts upon matter by other than mechanical laws. He thus regarded it as an "active principle," as opposed to the passive nature of matter, and he conjectured that God is the cause of the force of gravity that acts through this medium. In addition to its role in gravitation, Newton held that ether is the intermediary between light and ponderable matter, and irregular turbulence in it corresponds closely to his conception of heat. He suspected, though, that heat propagation and light propagation might require separate ethers.

Leibniz posed the question as to whether Newton's absolute space is altogether empty or whether it is full of extended spirits or immaterial substances capable of extending and contracting themselves. Newton's position is clear, and he went on to suggest that all nature might be alive, being composed of nothing but "various contextures of certain ethereal spirits" and possibly originating wholly from ether.[8]

Although Newton's theory of the ether aroused little initial interest, by the 1740's, natural philosophers elaborated on this concept. In their concept of nature, the ether is an active principle that functions as the source of all physical activity. During the eighteenth century, a strong difference in views concerning the ether occurred between French and British scientists. The French, following Descartes, who first introduced the concept of the ether into natural science, rejected Newton's inverse-square law of gravitation. Descartes' "ether" was different from Newton's. It was not qualitatively different from other forms of matter, nor did it have any activity that other forms of matter lack. It was merely a finely sub-divided form of matter, much like air, only more finely divided. The younger disciples of Newton were so antagonized that they responded by refuting not only the Cartesian ether but Newton's as well. Only in the second half of the eighteenth century did the ether regain respectability among Newtonians.

This rift hardened into a fundamental difference of views concerning the nature of scientific inquiry. The "continental school," as exemplified by Descartes (who by

[8] cf. Metaphysics and Natural Philosophy, P.M. Harman (Barnes & Noble Books, New Jersey, 1982) p. 25.

then had been dead for fifty years) and Huygens, took as one of the primary aims of natural philosophy the discovery and understanding of entities and mechanisms in nature that are hidden behind the veil of appearances. In his Principles Newton declares his task to be the mathematical explanation of observable phenomena without resort to hypotheses concerning unobservables; but elsewhere he presents elaborate speculations concerning the nature of such hidden entities as the ether and atoms. His young followers, in rejecting Cartesian thought, also disregarded these later, more metaphysical writings. They adhered to the principle that the aim of theoretical physics is simply the prediction of future events, and that everything which is not strictly needed for this purpose, and which is not strictly deducible from observed facts, should be discarded. Although this latter view gained a wide following in the eighteenth century, most physicists until the end of the nineteenth century adopted the attitude of the continental school.

From the birth of classical physics, concepts of space and the ether were inextricably intertwined with metaphysical assumptions and theological beliefs. Newton's theories were profoundly influenced by medieval metaphysics and theology, and his continental opponents were also well-versed in such thought. Newton was willing to refute the concept of matter as an absolute, independent reality on the grounds that it would lead to atheism; but he acknowledged such a reality for space since it is an attribute of God. Both Newton and his colleagues gave considerable effort to feigning hypotheses concerning the ether, which they formulated on both physical and metaphysical grounds. A modern physicist might claim that these early theories would have avoided many pitfalls if their creators had simply stuck to science, without muddling it up with extraneous philosophical and religious views. Leaving aside for the moment the feasibility of such an approach, we must recall that Newton regarded natural philosophy, or physics, as a means to commune with the Creator by better understanding His Creation. It was a religious pursuit. Scientific inquiry was in part an expression of religious piety; and without a metaphysical perspective, it could provide no view of the nature of physical reality.

During the opening decades of the development of classical mechanics, there were clearly profound differences of views concerning the nature of space and the ether. Schools of thought, Newtonian and Continental, arose, and their adherents forcefully attacked the views of their rivals on scientific, philosophical and theological grounds. No experiment, no empirical data was presented, that could settle the major disputes; rather the same body of evidence was interpreted in different ways and proffered in defense of incompatible theories. It seems that, at least during the infancy of modern physics, Nature was not as unequivocal in setting physical theories straight as one is often led to believe. She was indeed forthcoming when it came to hard facts, but the illumination to be derived from them became diffracted through the prism of human intelligence; and unintelligible unity became articulate diversity.

CHAPTER SIX:

EARLY CONCEPTS OF ENERGY

Other concepts of central concern to Newton and Leibniz were those of energy and force. Once again the views of these two men differed radically. The quantity that Newton defined as force (usually written F=ma) entails a concept that is imposed on essentially inert matter, and it is not conserved. We retain this usage of the term "force" to this day. Leibniz, in contrast, defined the "living force" (vis viva) of a body as a dynamical quantity (mv^2) that is conserved in all interactions. This concept is more closely akin to, and in fact helped to produce, our modern concept of "kinetic energy."

In his Specimen Dynamicum Leibniz set forth his notion of living force. He first draws a distinction between primitive and derivative forces. The former cannot suffice to explain phenomena, for they relate only to general causes and characterize the nature of substances. Derivative forces are those by which bodies act on one another. It is these forces that produce motion, and they arise through a "limitation" of primitive forces. The living force and the dead force (vis mortua) are derivative active forces; while the impenetrability of bodies and their resistance to motion are derivative passive forces. Derivative active and passive forces are both regarded as phenomenal manifestations of primitive forces.

As mentioned above, Leibniz defined the living force of a body as the product of its mass and the square of its speed. He adopted this quantity from Huygens, but while the latter thought it had no profound significance for the science of mechanics, Leibniz regarded the conservation of this quantity as a fundamental law expressing the inherent activity of nature and the order and self-sufficiency of natural processes. He writes in reference to this principle:

> We ought to establish...[a] law of nature which I hold as being most universal and most inviolable...there is always a perfect equivalence between the full cause and the total effect...each entire effect is equivalent to the cause.[1]

While living force arises in the actual motion of a body, dead force is the tendency of a body to achieve a state of motion. Thus the former arises from an infinite number of infinitesimal impulses of the latter. In Leibniz's view, matter is elastic and no change occurs

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[1]Reply to Catelan [1687], Philos. Schriften, Vo. 3, pp. 45-6. cf. Metaphysics and Natural Philosophy, P.M. Harman (Barnes & Noble Books, New Jersey, 1982) p. 37.

instantaneously but must pass through all intermediate degrees. This notion is an expression of his metaphysical principle of the "law of continuity." Although living force seems to disappear when a moving body comes to a stop as a result of friction, Leibniz assumed that it is simply absorbed into the internal structure of the bodies in question. While dead force is transient, living force remains in existence, conserved and never diminished.

In Leibniz's theology, God created a universe operating according to the perfect and self-sufficient laws established at creation. Due to the conservation of living force, natural processes are maintained without intervention by an external agent. Newton, however, maintained that every action in nature reflects the exertion of a new force on the thing acted upon. In nature there is a continual dissipation of motion that must be counteracted by "active principles"; thus the world cannot be reduced to absolute mechanism. He condemned Leibniz's notion of a world machine that can continue to run forever without divine intervention. In his <u>Opticks</u> he dismisses Leibniz's view of the conservation of living force as being sufficient to account for all natural phenomena, declaring this "a notion of materialism and fate,...[which] tends (under pretence of making God a <u>supramundane</u> intelligence) to exclude providence and God's government in reality out of the world."[2] Leibniz criticized Newton's theory as a supernatural doctrine of mechanics. Indeed, as mechanics developed over the following decades, the need for divine intervention or guidance (e.g. in maintaining the planets in their orbits) in nature did seem to disappear.

Thus, at the birth of classical physics there was a fundamental divergence of views by the two greatest natural philosophers of the time concerning the nature of force, energy and matter. The mathematical expressions for force promoted by Newton and Leibniz differed, as did their concepts of the matter that is acted upon by forces. Newton regarded matter as inert, and he challenged Leibniz's theory of the conservation of living force on theological grounds. The principle of conservation can be traced at least as far back as the fifth century B.C. in the speculations of the Greek philosopher Parmenides. Leibniz found it compatible with his theological views, and he criticized Newton's system of mechanics as being "supernatural." In the contest between these two intellectual giants in the history of science, neither adversary seemed concerned with "pure" science, divorced from metaphysics and theology. Nor, in their lifetime, did Nature settle their disputes.

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[2] cf. Introduction to Concepts and Theories in Physical Science, Gerald Holton (2nd ed., Addison-Wesley Pub. Co., Reading, Mass., 1973) p. 283.

CHAPTER SEVEN:

THE DEVELOPMENT OF THE PRINCIPLE OF THE CONSERVATION OF ENERGY

The formulation of the law of conservation of energy in the nineteenth century is one of the most striking instances of simultaneous discovery in the history of science. One factor contributing to this discovery was the belief, widespread in the eighteenth-century, in the interconversion of "natural powers" and the unity of nature. Speculations on the relationships among the phenomena of heat, light, electricity and chemistry were frequently based on a unified ether theory, which emphasized the balance of "forces," the unity and interconversion of natural phenomena, and the self-sufficiency of nature. More specifically, the Naturphilosophie (tracing back to Leibniz, the author of the metaphysical conservation theorem) could have provided an appropriate philosophical background for the discovery of energy conservation. Reaching its height of popularity during the first two decades of the nineteenth century, this view posited a universal science with organism as its fundamental metaphor; and its adherents constantly sought a single unifying principle for all natural phenomena.

In order for such a principle to emerge, a striking dichotomy in physical science had to be overcome. This disparity entailed one avenue of natural philosophy that had a strong qualitative and even metaphysical flavor, positing the existence of hidden entities such as the ether, and another that was chiefly quantitative, focussing chiefly on observable phenomena. This dichotomy is illustrated in the writings of Newton. We see, for instance, in his Opticks that he based his treatment of optics and chemistry on an experimental methodology and a speculative theoretical structure. In contrast, his Principles presents a paradigm of a mathematical science of "rational mechanics." In this discipline mathematical laws of mechanics were formulated on the basis of the concepts of mass, length and time; and unobservable, hypothetical explanatory entities were avoided. This disparity of methods was echoed in many of the eighteenth-century writings on physical theory. Even by the end of the century, imponderable, or unmeasurable, fluids were used to explain electricity, magnetism, light and heat. Those explanations were largely qualitative, while mechanical phenomena were studied mathematically; and hypotheses about atoms and the nature of forces were avoided.

An initial directive for overcoming this dualism was presented by Pierre Simon de Laplace. He and his followers formulated a mathematical theory of intermolecular forces to be applied to mechanical, thermal and optical phenomena. Stressing precise experimental work as a counterpart to mathematical physical theory, they sought a unification of mechanics and heat, light and electricity.

The availability of conversion processes was instrumental in the progress toward the energy conservation principle. This was made possible primarily due to the stream of discoveries that flowed from Alessandro Volta's invention of the battery in 1800. Twenty years later, Hans Oersted discovered the magnetic effects of an electric current. It was of course known that magnetism could produce motion, and that motion could produce electricity through friction. During the 1830's, scientists empirically explored ways of converting chemical, thermal, electrical, magnetic and dynamical phenomena into other phenomena. The convertability of such substances or processes did not guarantee the conservation of some "natural power" within them. For this, the presumably conserved entity had to be quantified, and the conversion processes alone made this extremely difficult. Nevertheless, due to the experimental and theoretical progress in the 1830's, it was possible to begin uniting previously detached branches of physics.

A major figure to bring the study of heat within the framework of mathematical analysis previously applied only to mechanical problems was Jean Baptiste Fourier. He postulated that all phenomena can be subsumed under mathematical laws. In 1822, he presented a theory of heat in which he dealt with it in a way analogous to Newton's treatment of gravity in his Principles: Its cause was acknowledged to be unknown, but its effects could be discovered by observation and subjected to mathematical analysis. Both men drew a distinction between mathematical theory and physical interpretation, and Fourier undoubtedly regarded the former as primary and as independent of the latter.

The concept of "work" was central to the quantitative analysis of heat and the formulation of the conservation laws. Although the quantity of the product of force times displacement in the direction of the force was given conceptual priority in dynamical theory in the late eighteenth century, it was not extensively utilized or propagated until the period 1819-1839. By then, theoretical treatises on mechanics emphasized the concept of work, defining it as the integral of force with respect to distance. This established a quantitative basis for conversion processes. In the meantime, Leibniz's concept of living force was redefined as $\frac{1}{2}mv^2$, thereby providing grounds for an explicit formulation of conservation laws in terms of equality of work done and living force created. Experimental confirmation of the quantitative equivalence of heat and work was provided in the 1840's by James Joule.

The concept of the ether was another factor in the nineteenth-century formulation of the law of the conservation of energy. During the second half of the eighteenth century, natural philosophers viewed the ether as an inherently active substance endowed with forces repulsive to gross objects as well as to particles of ether. This concept was elaborated into a unified ether theory which accounted for thermal, electrical and chemical phenomena. Due to the optical research of the physicists Thomas Young and Augustin Fresnel, by the 1820's, most scientists thought of light not as a substance (as posited by Newton) but as a wave motion in the ether (as originally suggested by Huygens). This ether was regarded as the mediating substance for both the propagation of light and for electric and magnetic interactions. Recognizing the transverse wave property of light, Fresnel concluded that the ether must have rigidity; for a fluid ether could not produce such vibrations. Fresnel rejected the distinction between ordinary and imponderable substances. For him, the ether was a form of ordinary matter bearing mechanical properties, and this theory helped make optics a quantitative science and bring it into accord with the mechanical view of nature. The wave theory of light suggested that heat, too, is a wave phenomenon, and during the first half of the nineteenth century, many scientists did accept the principle of the qualitative identity of heat and light. By the 1830's, the fundamental identity of heat, light and electricity was seen in the context of the dynamics of the ether, whose motions were responsible for the transmission of these phenomena. This concept replaced that of imponderable fluids and became the basis for a unified physics.

The conversion processes and mathematical analyses of heat and electricity in the nineteenth century were prerequisites for the formulation of the principle of energy conservation. Part of the foundation for this principle was the refutation of perpetual motion. Early in the nineteenth century, as new conversion processes were developed, some scientists, ignoring irreversible energy transformations, reasoned that any "power" can produce any other and be produced by it. Therefore, there must be a uniform, quantitative equivalence between each pair of powers; otherwise, a properly chosen series of conversions would result in the creation of power. On this basis, a law of conservation was formulated as early as 1829. In 1840, Michael Faraday proposed such a principle, and in 1842, Julius Mayer declared that "forces" are indestructible, convertible entities. Mayer's thesis, however, was philosophical in nature; and, lacking a solid experimental basis and mathematical formulation, it was ignored for at least a decade.

Mayer's theory and the work of Joule are often contrasted: the former exemplifying a non-scientific, speculative approach to nature, and the latter typifying the sober, empirical and mathematical approach of a physicist.

The point is well taken. Nevertheless, it is worth noting that Joule did not present a quantitative formulation of a general principle of conservation of energy. Rather, he maintained that he had scientifically established the mutual convertability of heat and work. He did in fact believe in the indestructibility and self-sufficiency of "natural powers"; but on what grounds?--Only God can destroy agents of nature. It is "manifestly absurd," he declared, "to suppose that the powers with which God has endowed matter can be destroyed."[1] Both he and Faraday argued that the indestructibility of such powers is an indication of the wisdom and foresight of God.

For Mayer the notion of an underlying, imperishable metaphysical force seems prior to research and almost unrelated to it. The same has been said of Hermann von Helmholtz[2], and it was he who in 1847 provided the first systematic and mathematical formulation of the principle of the conservation of energy. In an essay presented in that year, he treated mechanical phenomena, heat, light, electricity and magnetism as different manifestations of energy. On this basis he devised a conservation law in the

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[1] cf. Introduction to Concepts and Theories in Physical Science, Gerald Holton (2nd ed., Addison-Wesley Pub. Co., Reading, Mass., 1973 p. 272.

[2] cf. "Energy Conservation as an Example of Simultaneous Discovery" in The Essential Tension: Selected Studies in Scientific Tradition and Change, Thomas Kuhn (Univ. of Chicago Press, Chicago, 1977) p.94.

form of a mathematical and mechanical theorem. This formulation was closely linked to his assumption of the universal validity of the mechanical view of nature. This, he assumed, was the criterion for "the complete comprehensibility of nature,"[3] and he emphasized the unifying role of the energy concept in relation to an ontology of matter and the program of mechanical explanation. In taking this view, he assumed that natural laws are objectively real and cause phenomena, and that those laws are Newtonian.

From the foregoing discussion it is apparent that during the first half of the nineteenth century there was bound to be some confusion in terminology relating to the conservation of energy. The word "energy" used roughly in the modern sense dates from 1807, but for decades thereafter different scientists variously spoke of "natural powers" and "forces" that are conserved. "Energy" was first used as a general and fundamental physical concept by William Thomson in 1849. He identified two types of energy, which he called "statical" and "dynamical" and maintained that all forms of energy are of a mechanical nature. Thus, energy became for him the unifying principle in physics. In his view, it is an objectively real, quantitatively immutable entity that is convertible and links all of nature in a web of energy

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[3] Energy, Force and Matter: The Conceptual Development of Nineteenth Century Physics, P.M. Harman (Cambridge Univ. Press, Cambridge, 1982) p.43.

transformations. Like so many other scientists, he too expressed a theological position in support of his theory: Energy is an immutable natural agent that cannot be created or destroyed except by God. His metaphysical assumption was that the energy concept would provide a foundation for a comprehensive, mechanical explanation of natural events.

Thomson's use of the word "energy" resolved terminological and conceptual confusions, and his emphasis on diverse energies being manifestations of mechanical energy brought out the unifying role of this concept. By the 1850's, this term was in common usage, though it was not until 1867 that the dual classification of "potential" and "kinetic" energy was introduced.

The principle of energy conservation was a broadly unifying factor in nineteenth-century physics. As we have seen, the motivation for its adoption into scientific theory arose largely from a metaphysical assumption of the unity of nature. Leibniz, the author of the metaphysical conservation theorem, formulated this concept long before conclusive empirical evidence was available to substantiate it. He simply intuited, for example, that live force (akin to the modern concept of kinetic energy) must be conserved, even though experience suggested otherwise. Mayer and Helmholtz first adopted the conservation principle on metaphysical grounds, while Joule, Faraday and Thomson formulated scientific theories of this principle in conformity with their theological views. It seems that it never entered their minds that science could be conducted properly only when it is divorced from metaphysics and religion; and the conservation theory that they pioneered remains as perhaps the dominant principle of twentieth-century physics.

CHAPTER EIGHT:

NINETEENTH-CENTURY CONCEPTS OF THE ETHER

Just as the concept of energy provided a unifying link between mechanical and thermal phenomena, so did the concept of the field bring electricity, magnetism, light and gravity into a common framework of physical theory. A field, simply stated, is a form of energy in space, and it is intimately related to the ether. Thomas Young, for example, conceived of ethereal atmospheres surrounding particles of ordinary matter, and the concept of a luminiferous ether became a central feature of his optics. Fresnel, too, believed that optics could be explained in terms of vibrations of an ether bearing mechanical properties, and he envisaged a unified physics based upon this concept.

It was Michael Faraday who, in 1845, introduced the term "magnetic field." His concept of the field was intimately related to his theory of matter. In his view, each atom extends in all directions continuously, yet always retains its own center of force. He thus rejected the Newtonian concept of spatially isolated particles acting upon one another through the agency of an interatomic void. Matter, he argued, should be represented as a plenum of "powers," and individual particles are to be regarded as centers of force. Thus, force is the defining property of matter (rather than something external to it), and since matter is continuous throughout space, electrical and other forces are transmitted without having to consider atoms and the intervening space. Faraday maintained that real, physical electric and magnetic lines of force emanate from particles and thereby influence (or create) their surroundings. He eventually extended his theory of the field to explain gravity as well. Without exploring the issue, it is worth noting in passing that metaphysical argument and the problem of substance were prominent in Faraday's theory of the physical field.

James Clerk Maxwell was among the physicists who adopted the field concept, and in 1865 he gave it its first clear definition. A field, he said, is a property of the ambient space that mediates forces between bodies. Its physical structure is mathematically expressed by partial differential equations, and it is represented dynamically as energy transformations in the ether. It is important to note that Maxwell viewed energy as the fundamental constituent of physical reality, and the law of conservation of energy as the unifying dynamical principle.

Maxwell made the most systematic attempt to develop Faraday's theory of the physical field. He maintained that the ethereal medium which constitutes the field, existing in absolute space, is the repository of its energy. Early on he devised a theory of a mechanical ether composed of elastic cells. However, he intended this as an illustrative model rather than an ultimate physical explanation; and he eventually abandoned the attempt to specify the mechanical nature of the ether. With unusual philosophical insight, he recognized the danger of assuming that one and only one hypothesis is validated by the experimental confirmation of conclusions drawn from it. Thus, he saw that if there is one mechanical model of the ether that could be proposed as a hypothesis, there are an infinity. Any experimental data, he saw, confirm a set of hypotheses, not a unique one. The nature of substance, he declared, cannot be established simply by an appeal to empirical data and laws; one must also refer to metaphysical argument.

In harmony with this view, Maxwell employed methods of Lagrangian analytical dynamics, a generalized formalism not linked to any specific model. While insisting that the energy of a field is a physical reality, not merely an analogy or an illustration, he maintained that it can be specified without reference to a hidden structure. The unification of optics and electromagnetism, in which he played the key role, further strengthened his confidence in the physical existence of the ether; and Heinrich Hertz's experimental confirmation of electromagnetic waves added yet more evidence in support of this concept. Despite Maxwell's realization of the problems of hypothesizing hidden structures, he nevertheless envisaged the possibility of a mechanical model of the ether that is fully consistent with physical reality.

During the 1880's, scientists engaged in extensive debates concerning the physical status of the ether and its relationship with electromagnetic waves. Until the closing years of the nineteenth century, most physicists, including Maxwell, advocated an ether with mechanical properties. Indeed, the confirmation of such an ether would have been the ultimate triumph of classical mechanics and the attainment of the goal of a complete, mechanical understanding of nature. However, attempts to formulate an ether theory consistent with experimental evidence (most notably the Michelson-Morley experiment of 1887) seemed to "account for appearances" in an artificial and ad hoc way.

Hendrik Lorentz adopted a new attitude toward the ether: He proposed an electromagnetic ether that is free of all mechanical properties, and suggested that the laws of nature be reduced to properties defined by the electromagnetic field equations. In his view, electromagnetic fields and the ether are independent physical realities. By the turn of the century, many physicists had adopted this idea and believed that an ether divorced of all mechanical properties would provide the basis of all physical theory.

As one examines the history of nineteenth-century physics, one is struck by two major characteristics of this era. Among the scientific community there grew a widespread agreement that the conservation of energy was a fundamental element of Nature; and this principle was a central unifying concept of physical theory. There was a consensus that energy bears an independent physical reality and that it is conserved. But what is the nature of this conserved entity? Mathematical formulas and experimental data demonstrated a balancing of the ledger in conversion processes, but they do not say what is happening "behind the scene of appearances." Thus, while there was uniformity of opinion that energy is conserved, there came to be a great diversity of views concerning the meaning and mechanism of energy conservation.

The concept of energy was intimately related to those of matter, fields and the ether. Nineteenth-century concepts of matter varied widely, as we see in the contrast between the traditional Newtonian view and the radical departure of Faraday's thinking. Wide-ranging speculation on the existence of atoms occurred, and a diversity of fertile imaginations were at work devising theories of the field and the ether. All of these, as Maxwell observed, were based upon metaphysical argument--the bare calculations and data provided no theory on their own.

CHAPTER NINE:

NINETEENTH-CENTURY CONCEPTS OF SPACE

As Newton's science of mechanics gained in recognition, so did his concept of absolute space; and by the early eighteenth century, his divinization of space also became popular in conformity with the view that science is the study of the works of God. However, further developments in mechanics by such physicists as Lagrange, Laplace and Poisson made few explicit references to this concept, presumably out of lack of interest. Indeed, Laplace felt such confidence in the comprehensive explanatory power of mechanics that he saw no need to introduce the hypothesis of God to account for natural phenomena. Newton assumed that God not only created the universe but continued to participate actively in directing the course of natural events. Nineteenth-century physics, with its emphasis on the self-sufficiency of Nature by means of the conservation of energy, seemed to imply that God's involvement in natural events need not be as active as previously supposed. Newton's prediction that the concept of energy conservation would lead to materialism and atheism seemed well on its way to fulfillment.

During the nineteenth century, Lobachevski, Bolyai and Riemann devised non-Euclidean systems of geometry, thereby laying grounds for questioning the synthetic _a prior_ nature of Euclidean geometry. Riemann demonstrated that the space of Euclidean geometry and the space of the geometries of Lobachevski and Bolyai are special cases of generalized space, entailing spaces of zero curvature and constant negative curvature respectively. In Riemann's view, the metrical structure of space is determined by the distribution of matter, and space is homogeneous only if one ignores matter. The advent of these unorthodox geometries suggested that pure axiomatic geometry may be a hypothetical, mathematical system, rather than a branch of mechanics, as Newton had believed.

Which of the mathematical constructs corresponds to the geometry of physical space? Helmholtz, along with many other scientists rejected Kant's assertion of the synthetic _a priori_ nature of Euclidean geometry. He declared that the geometry of physical space must be decided by empirical means; no longer was it possible simply to assume that it was uniquely represented by Euclidean geometry. Lobachevski tried and failed to prove the non-Euclidean structure of physical space and concluded that Euclidean geometry is the only one of importance for practical purposes. In the 1820's, Gauss, too, investigated the nature of physical space. He likewise assumed that space has a reality outside the mind and that its structure cannot be prescribed *a priori*. He sought experimentally to determine the structure of physical space, but found no empirical evidence for non-Euclidean geometries. Like Lobachevski, he returned to the belief that Euclid's system corresponds to the geometry of physical space.

By the end of the nineteenth century, the issue remained undecided, and three options remained open: (1) Riemannian curvature is everywhere zero and physical space is Euclidean, (2) it is a positive constant and space is spherical, or (3) it is negative and space is hyperbolic. Henri Poincaré, however, cast a new light on the entire question. He declared that it is impossible to determine empirically which of the above mutually exclusive geometries describes real space. Measurements are always of physical objects in space, so experiments could show only the relations among those objects.[1] If, for example, one found that light curves, one could equally conclude that it follows the shortest route in curved space or that it follows a curved path in Euclidean space--and no experiment can decide the question one way or the other. In short, according to Poincaré, experience can neither confirm nor refute any geometry. The alternative is to select the geometry which enables us to formulate the laws of nature in

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[1] *Concepts of Space*, Max Jammer (Harvard Univ. Press, Cambridge, Mass., 1954) p. 162.

the simplest way; i.e. to take a pragmatic stance without making ontological claims.

Returning to the concept of absolute space, it became increasingly clear during the nineteenth century that such a theory was useless in physical practice. In the words of Maxwell, "there is nothing to distinguish one part of space from another except its relation to the place of material bodies...All our knowledge, both of time and space, is essentially relative."[2] The first persuasive refutation of the concept of absolute space was produced by Ernst Mach. Centrifugal forces (as in Newton's revolving pail experiment), he showed, can be explained in terms of the distribution of other distant masses in the universe, without resorting to absolute space. Thus, due to the intrinsic functional dependence between inertia and the large-scale distribution of matter, Newton's concept is unnecessary. Mach's refutation of absolute space was simply one facet of his intention to eliminate all metaphysical concepts from science. Hypothetical physical objects, such as atoms, that are not subject to experience, must, he thought, be banished from science. By the end of the nineteenth century, it was obvious that absolute space evaded all experimental means of detection.

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[2] Matter and Motion, J.C. Maxwell, reprinted with notes and appendices by Sir Joseph Larmor (Dover, New York, n.d.) p. 12. cf. Concepts of Space, p. 140.

The nineteenth century introduced an unprecedented diversity of geometries, and this entailed an unprecedented confusion as to the geometry of physical space. Many physicists, like Helmholtz, maintained the traditional creed that empirical evidence would decide which among the different geometries corresponds to reality. But the closing decades of this century stimulated several outstanding scientists, notably Maxwell, Mach and Poincaré, to question that assumption. Poincaré went so far as to suggest that there is no strictly correct geometry for the description of space.[3] The absolute nature of space was also brought into question by such thinkers as Maxwell and Mach. Moreover, while the former gradually disengaged himself from speculations on theoretical entities, such as the ether, hidden behind the veil of appearances, Mach banished such metaphysical intrusions on science altogether. He was hardly alone, in the late nineteenth century, in his exasperation with fruitless philosophical speculation. In 1874, the noted physicist Peter Tait remarked:

> The fundamental notions which occur to us when we commence the study of physical science are those of Time and Space...But we cannot inquire into the actual nature of either space or time, except in

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[3] "The Curvature of Space in a Finite Universe," J.J. Callahan, Cosmology + 1 (W.H. Freeman and Co., San Francisco, 1977).

the way of purely metaphysical, and therefore of necessity absolutely barren, speculation.[4]

The diversity of views concerning the nature of space, time matter and energy, that had always be prevalent in the development of classical physics was now compounded and further confounded with a divergence of views on the role of such concepts in natural science.

[4] "Lectures on Some Recent Advances in Physical Science," P. Tait, p. 4. Cited in The Ethereal Aether by Loyd S. Swenson, Jr. (University of Texas Press, Austin, 1972) pp. 28-29.

CHAPTER TEN:

THE ETHER AT THE CULMINATION OF CLASSICAL PHYSICS

As noted above, Poincaré differed from most of his predecessors, including Newton and Gauss, by removing geometry from the domain of natural science and stating that our choice of the geometry of physical space is a matter of convention. Albert Einstein, the last of the great classical physicists, responded that Poincaré was only partly right: Geometry is purely a matter of convention only if one makes no assumptions concerning the behavior of physical bodies. As soon as ontological claims are made in reference to such behavior, parameters are established for the geometric system that can be applied. In other words, while neither the behavior of physical bodies nor the geometry of space can be determined simply by empirical evidence, assumptions about one set parameters on the other.

In terms of the physical concept of the ether, Einstein felt that Lorentz made a major advance by divorcing it of mechanical properties. The one mechanical property that remained, under Einstein's penetrating scrutiny, was immobility. His special theory of relativity removes that last mechanical quality, but in so doing, it does not refute the existence of ether. Rather, it prohibits us from ascribing a definite state of motion to it, and denies that it consists of particles observable through time.

Einstein's concept of the ether is more fully developed in his general theory of relativity. While rejecting the concept of absolute space, he does suggest that an ether serves as a medium for the effects of inertia. Such an ether not only conditions the behavior of inert masses but is also conditioned in its state by them. Space, then, is not physically empty, but is filled with an ether, devoid of all mechanical and kinematical qualities. In contrast, the state of the Lorentzian ether in the absence of electromagnetic fields is conditioned by nothing outside itself, and is everywhere the same.

Although Einstein is commonly thought to have removed the ether completely from the domain of science, this is clearly a fallacy. In his essay "Ether and the Theory of Relativity" he writes:

> There is weighty argument to be adduced in favour of the ether hypothesis. To deny the ether is ultimately to assume that empty space has no physical qualities whatever. The fundamental facts of mechanics do not harmonize with this view.[1]

From Einstein's perspective, modern physics is presented with two types of phenomena that are conceptually completely separate and causally connected: namely,

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[1] Sidelights on Relativity, A. Einstein, trans. G.B. Jeffrey and W. Perrett (Dover Publications, Inc., N.Y., 1983) p. 16.

gravitational ether and the electromagnetic field (including particles of matter, since they are, in his words, simply condensations of the electromagnetic field).[2] To the end of his life he sought to comprehend these two--essentially space and matter--as one unified system. He was particularly drawn to the possibility of devising a physical theory of pure fields, devoid of the concept of matter. The major problem, as he saw it, was to modify the field laws in such a way that they would not break down for regions in which energy is enormously concentrated.

Einstein clearly recognized that experimental facts neither produce scientific theories, nor can they prove the validity of any theory that explains the nature and laws of hidden entities; for mutually incompatible theories can explain the same data with equal consistency. However, he was in no way prepared to cease devising such ontological hypotheses. The greatest single achievement of Newtonian mechanics, he claimed, is that it led <u>beyond</u> the phenomenological representation of Mach.

Einstein regarded physical concepts as free creations of the human mind and not uniquely determined by the external world; and yet he maintained that without the belief that it is possible to grasp reality with our theoretical constructions, there could be no science. A civilization under different circumstances might have developed a physical science profoundly different from ours.

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[2] <u>ibid</u>., p. 22.

However, he believed that in the evolution of ideas, present-day physics won out over alternative systems, and that its dominance gives us grounds for believing that in large part it describes the real physical world. The relation between physical theory and reality can, he claimed, be understood only intuitively.

To the end of his life Einstein believed in the possibility of a model of reality, of a theory, that represents nature itself. In his quest for truth he was moved by a cosmic religious feeling which he held to be the strongest and noblest motive for scientific research. This feeling entailed a belief in the intelligibility of the world. It was, in his words, a "firm belief, a belief bound up with deep feeling, in a superior mind that reveals itself in the world of experience."[3]

Modern physics textbooks tend to give a very straightforward account of the change of attitude concerning the ether as a result of the Michelson-Morley experiment[4] in 1887 and Einstein's special theory of relativity presented in 1905: The former presented strong negative evidence that cast doubt on the existence of the ether, and the latter made it a theoretical impossibility. Moreover, it is frequently suggested that Einstein formulated special

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[3]"On Scientific Truth" in Ideas and Opinions, A. Einstein, based on Mein Weltbild, ed. by Carl Seelig, etc.; trans. and revised by Sonya Bangmann (Crown Publishers, Inc., N.Y., 1954) p. 262.

[4]cf. Modern Physics, Paul A. Tipler (Worth Publishers, Inc., N.Y., 1978) pp. 5-8.

relativity in response to that experiment. Such as account is misinformed and misleading. In fact, Einstein was not aware of the Michelson-Morley experiment as he developed this theory; nor, as we have seen, did either the empirical evidence or the theory refute the existence of the ether altogether. The classical concept of the ether did indeed have to undergo modification.[5] In reference to that concept, Einstein and Infeld declared, "All assumptions concerning either led nowhere!"[6]

A few years after the Michelson-Morley experiment, Lord Kelvin expressed the general attitude of physicists, saying, "One thing we are sure of, and that is the reality and substantiality of the luminiferous ether."[7] Sir J.J. Thomson, the recipient of the 1906 Nobel prize in physics, declared that all mass and kinetic energy is composed of the ether,[8] and Einstein himself insisted that the existence of the ether cannot be denied. Nevertheless, today's students of physics are taught that science had empirically and theoretically refuted this naive concept by the first decade of this century.

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[5]Note the parallel in terms of Boyer's insights into blackbody radiation and necessary modifications in classical thermodynamics. Nature did not demand the adoption of quanta anymore than the abandonment of the ether.

[6]The Evolution of Physics, Albert Einstein and Leopold Infeld (A Touchstone Book, Simon and Schuster, N.Y., 1966, orign. pub. 1938) p. 175.

[7]Cited in Quantum Reality: Beyond the New Physics, Nick Herbert (Anchor Press/Doubleday, Garden City, N.Y., 1985) p. 7.

[8]Ether and Reality, Sir Oliver Lodge (George H. Doran Co., N.Y., 1925) p. 91.

The classical concept of a luminiferous ether was regarded as an indispensable medium for the transmission of electromagnetic waves. Electromagnetic phenomena exhibited wavelike characteristics, and all other types of waves required a medium through which to travel. Waves might travel through a solid, liquid or gas, but electromagnetic waves had the unusual quality of traveling even through the vacuum. It naturally followed that empty space had to be permeated with an ethereal substance that could transmit such waves. Contemporary physics students are told that this belief is naive and antiquated. The modern creed is that no such medium is necessary. Mechanical waves traveling through a solid, liquid or gas are understood only in their interaction with a transmitting substance: It is the medium that fluctuates. But electromagnetic waves are not fluctuation of anything else; they are simply waves of themselves. If we find this explanation less than satisfactory, we can at least be comforted with the thought that we are in good company. Einstein and Infeld commented on this subject:

> Our only way out seems to be to take for granted that space has the physical property of transmitting electromagnetic waves, and not to bother too much about the meaning of this statement.[9]

[9] The Evolution of Physics, p. 153.

PART THREE:

EXPLORING THE FOUNDATIONS OF PHYSICS

CHAPTER ELEVEN:

PHYSICS AND REALITY

An inspection of the history of physical theories in modern science reveals a great diversity of beliefs concerning the nature of space, matter, energy and matter. Although there is widespread agreement among physicists concerning the use of mathematical techniques, the validity of empirical data and the value of certain models of physical processes as <u>heuristic</u> devices, fundamental diversity of opinion persists concerning the nature of physical reality. Among the various areas of dissention that we have examined, certainly the most fundamental problem is the relation between physical theory and physical reality.

Many scientists and their followers in the nineteenth century adhered to a view of physics now described as <u>realism</u>: Physical theory corresponds to an independent objective reality. Theoretical entities, such as gravity, fields, energy and the ether, operate behind the veil of appearances; and their existence is discovered by unbiased research. The laws of Nature are revealed by the scientific method, entailing mathematical analysis and empirical verification, and they describe physical events that occur independently of the human mind.

During the latter part of the nineteenth century, this metaphysical assumption was challenged, as we have seen, by such physicists as Maxwell, Mach and Poincaré. Their views are closely aligned with a philosophy of science presently known as instrumentalism: The function of a physical theory is to offer an intelligible, systematic conceptual pattern for observed data, thereby uniting phenomena that are otherwise surprising, anomalies or wholly unnoticed.[1] Theoretical concepts, such as fields, energy, electron and so on, do not correspond to independent, objective entities; they are simply conceptual constructs, or instruments, that physicists find useful in making predictions about measurements. Thus, physical theories are not true or false; they are simply more or less useful in accounting for observed phenomena.

The fundamental opposition of realist versus instrumentalist views did not emerge for the first time in

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[1] The Concept of the Positron: A Philosophical Analysis, Norwood Russell Hanson (Cambridge Univ. Press, London, 1963) p. 44.

the nineteenth century. The beginnings of this controversy can be traced back to Greek antiquity.[2] [3] One of the challenges that Plato set for his students was to devise a mathematical stratagem that would account for the motions of heavenly bodies.[4] The first reasonably complete astronomical theory known to history was formulated in this spirit by Eudoxus. His motive was to "save the appearances," and his theory entailed a mathematical description rather than a physical explanation.[5] Aristotle, on the other hand, was concerned with an astronomical theory that explained <u>why</u> celestial bodies move as they do. The hypotheses of such a theory must be justified by the nature

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[2]For a more extensive account of the history of this ontological debate, see <u>To Save the Phenomena: An essay on the idea of physical theory from Plato to Galileo</u>, Pierre Duhem, trans. by E. Doland and C. Maschler (Univ. of Chicago Press, Chicago, 1969).

[3]In the following discussion the terms "realism" and "instrumentalism" are applied to the views of thinkers going all the way back to Eudoxus. I have thereby taken certain liberties in the usage of these modern terms, but I believe this is justifiable in order to accentuate recurrent themes in the foundations of physical theory.

[4]Plato may have encouraged an instrumentalist view concerning the project that he set for his astronomy students, but he can in no way be regarded as a throroughgoing instrumentalist. On the contrary, many of his views are clearly those of a realist.

[5]A theory that "saves the appearances" accounts for observed phenomena, such that their present occurence is seen as a matter of course, and future occurrences are accurately predicted. This is also what is meant by "saving the phenomena." Such a theory makes phenomena intelligible in the sense of <u>predicting</u> their behavior, without <u>explaining</u> why they behave as they do.

of those bodies, and not simply account in an ad hoc manner for their movements.

Given the challenge of saving the appearances, Greek astronomers were quick to discover that more than one theory could account for the same observed phenomena. Hipparchus (2nd century B.C.) proved, for example, that the course of the sun can be represented either by supposing that it describes a circle eccentric to our world, or by letting it be carried by an epicycle. In the latter case, the revolution of this epicycle must be achieved in exactly the same time in which its center has completed a circle concentric with the earth.

Ptolemy (2nd century C.E.), whose astronomical system was extensively elaborated during the Middle Ages, was another thinker who adopted an "instrumentalist" view concerning physical theory. In his system the spheres and orbits of the celestial bodies, by which appearances were to be saved, were regarded as "hypotheses" in the strict sense of the word: assumptions made for the purpose of a particular argument, and by the same token not posited as true.[6] The Greek and medieval astronomers who adhered to his instrumentalist view were not at all disturbed by the fact that the same appearances could be saved by two or more quite different hypotheses, such as an eccentric or an

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[6] Saving the Appearances: A Study in Idolatry, Owen Barfield (Faber and Faber, London, 1957) p. 49.

epicycle. They were concerned simply with finding the simplest and the most complete theory for practical purposes.

While Aristotle claimed to have found the fundamental principles of both the sublunary and celestial realms, the fifth-century Greek philosopher Proclus declared that there is a fundamental distinction between human knowledge of those two realms. While humans can understand sublunary things, he maintained, our hypotheses concerning heavenly things are at best approximations; for the same conclusions can be drawn from different hypotheses concerning the same phenomena. Only the divine Mind (logos) knows what the heavens are really like. A realist at heart, Proclus was thus obliged to introduce an element of uncertainty into human understanding of celestial objects.

As Ptolemaic astronomy was adopted and further developed first by Arabic thinkers and later by medieval Christian scholars, the original intent of Ptolemy was forgotten. The Arab philosopher Averroës (12th century), for example, required more of astronomy than its simply accounting for appearances. Its hypotheses must be justified in accordance with principles of physics, namely those set down by Aristotle. Bernard of Verdun, a medieval Scholastic doctor, further retreated from the wisdom of the Greeks by maintaining that a false hypothesis--i.e. one that does not describe physical reality--cannot possibly yield exact, correct predictions. Aquinas, on the other hand, recognized, along with Averroës, that a hypothesis may yield predictions that agree with observation, without that hypothesis thereby being established as a demonstrated truth. Medieval Christian astronomers placed two basic demands upon the hypotheses of astronomy: (1) They should be as simple as possible and (2) they should save the appearances as exactly as possible.

The task that Copernicus set himself was to save the appearances by means of hypotheses conformable to the principles of physics. Like Averroës, he regarded an astronomical theory as satisfactory only if it is constructed on the basis of hypotheses that are <u>true</u>. Following the philosophical position of his medieval predecessors, he, too, deviated from Ptolemy by taking a realist view of the hypotheses of astronomy.

Kepler adopted both the heliocentrism of Copernicus and his attitude regarding hypotheses. He recognized that mathematics alone cannot decide among diverse hypotheses--i.e. mathematical formulas are not self-interpreting. Rather, the choice must be made on the basis of justifiable physical principles. Moreover, he was convinced that if a hypothesis is not true, its falsehood will be revealed when it is applied with sufficient precision to ever more varied cases.

Galileo, too, demanded that the hypotheses of astronomy be established on the ground of physics. As the father of modern science, he is heralded for his insistence that experience, and not the authority of tradition, decide which among competing hypotheses conforms to reality. With his dedication to realism, he seems to have ignored that contradictory hypotheses may equally account for the same observed facts. Moreover, in his contest with the Inquisition, he exhibited an even more simplistic attitude concerning the proof of a hypothesis. In imitation of the *reductio ad absurdum* proofs that are used in geometry, he suggested that experience, by convicting one system of error, confers certainty upon its opposite.[7]

The first religious opposition to the heliocentric theory came not from the Roman Catholic Church, but from Martin Luther. Recognizing that its chief proponents regarded it as being a true hypothesis, and not merely a useful instrument for making predictions, Luther condemned it as contrary to Scripture. His disciple Melanchthon proceeded to warn young people to rely upon religious authority and not to be misled by the hypotheses of "clever scientists." In his words: "They will then understand that

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[7] *To Save the Phenomena*, p. 109.

God has revealed the truth; they should accept it with respect and acquiesce in it."[8]

Until the culmination of the conflict between the Inquisition and Galileo in 1616, the Church of Rome not only permitted but encouraged discussion of the Copernican system, as long as it was confined to the language of science and did not impinge on theological matters.[9] The dignitaries in the Vatican apparently believed that Copernicus presented his theory as a hypothesis in the traditional sense of the word: a useful means to save the appearances and make accurate predictions, without any claim to truth. Galileo's chief opponent in the controversy with the Church was Cardinal Robert Bellarmine. A general of the Jesuit Order, he found nothing to be prohibited in the Copernican theory as long as it was introduced simply in order to save appearances. Indeed, he maintained that

> to say that the assumption that the Earth moves and the Sun stands still saves all the celestial appearances better than do eccentrics and epicycles is to speak with excellent good sense

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[8]Initia doctrinae physicae dictata in Academia Vuitebergensi, 2nd. ed. (Wittenberg: Johannes Lufft, 1550) fols. 39-42. Cited in To Save the Phenomena, p. 88.

[9]The Sleepwalkers: A History of Man's Changing Vision of the Universe, Arthur Koestler (The MacMillan Co. N.Y., 1959) p. 357.

> and to run no risk whatever. Such a manner of speaking suffices for a mathematician.[10]

However, he went on to insist that one should not think that the sun is in truth at the center of the universe. Thus, the Church naturally held a realist view regarded its own scriptures and tolerated contrary scientific theories only if they were presented from the instrumentalist point of view. Galileo found such intolerance unacceptable. The Church's inability to accept a realist interpretation of heleocentrism resulted in its condemnation of the Copernican system in 1616. Shortly thereafter, Cardinal Maffeo Barberini, soon to become Pope Urban VIII, met with Galileo to discuss scientific theory and reality. The Cardinal pointed out that to prove your own hypothesis, you must demonstrate that its predictions could not be obtained by a different system and that such a system would involve contradiction. The fact that a hypothesis, such as the heliocentric theory, satisfactorily explains certain phenomena does not necessarily prove that it is true, for those phenomena could have been produced by some entirely different means which are not understood by the human mind.

Seen in this light, the conflict between Galileo and the Church appears to focus on the ontological assumptions concerning physical theory. Galileo was unpersuaded by the

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[10] From a private letter, cited in The Sleepwalkers, p. 447.

Cardinal's critique of his realist view of scientific theory, and he must have recognized that the Church was unwilling to apply that same critique to its own interpretations of theories presented in the scriptures. Since Galileo was impenitent in his realism, in 1633 Urban VIII allowed the Peripatetics of the Holy Office to express their intransigent realism by issuing a further condemnation of the Copernican system. Galileo was forbidden to teach that system in any manner whatsoever. From now on astronomy was to be subject to theology and philosophy, and the Copernican hypotheses were not to be used even to make predictions.

Although Copernicus, Kepler and Galileo were all confirmed realists, the contest between instrumentalism and realism among scientists was far from settled. As we have seen, Newton himself was of two minds on the matter. In his _Principles_, he restricted himself to setting forth the mathematical principles of mechanics as a means of understanding apparently diverse physical phenomena, notably both terrestrial and celestial dynamics. With this system he was able to vanquish the mistaken assumption--tracing back to Aristotle--that sublunary and celestial bodies are subject to fundamentally different natural laws. His theory also challenged the view of Proclus to the effect that only sublunary events can be humanly known with certainty. In this treatise he made a point of not speculating on the ontological nature of such theoretical entities as gravitational force. To Leibniz, his chief opponent, Principles seemed merely a mathematical predicting device, akin to Ptolemy's system of astronomy: They both merely saved the appearances, while providing minimal elucidation of the actual nature of physical reality.[11] For Leibniz and other like-minded Continental thinkers, a complete science must explain the data, as well as account for them. Thus, following the trend of Aristotle, Leibniz adopted a realist view, while criticizing Newton for his instrumentalist leanings. This charge is only partially justified. Newton did indeed seek to abstain from feigning ontological hypotheses by confining himself to observable phenomena; and even in his later years he discouraged his students from speculating on the physical nature of gravity. Nevertheless, as evidenced in his Opticks, he was not immune to hypothesizing various types of ether that could act as media for gravity, light and heat. His metaphysical and theological convictions concerning the nature of space, time, force and matter are also incompatible with an instrumentalist view.

Throughout the eighteenth century, as Newtonian mechanics was extended and refined, it was widely regarded as a mathematical theory designed to predict, but not to

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[11]cf. The Concept of the Positron, p. 34.

explain, physical phenomena. But during the nineteenth century, a process of reification dominated scientific thinking, and mechanics came to be regarded as a true explanation of the hidden processes of physical reality, behind the veil of appearances. This mechanical philosophy can be traced back at least to the 17th century, and though it originated from no single thinker, its most influential proponent was Descartes.[12] He held that Nature contains no unfathomable mysteries and that it is wholly transparent to reason. While rigidly excluding all cognitive elements from the material world, he asserted that all phenomena of nature are produced by inert matter in motion. A central assumption of his philosophy is that physical reality is not in any way similar to the appearances of sensation. Although he acknowledged the existence of a non-material soul (for humans only), this was not the seat of life; and he described all organic functions in purely mechanistic terms.

Like Descartes, Galileo was committed to the belief that the physical world is composed of certain primary properties and it can be known only in mathematical terms. Human minds and individuals are not included in that realm, and in Galileo's view they are relegated to little more than

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[12]For a more detailed discussion of this mechanical philosophy see Richard S. Westfall's The Construction of Modern Science: Mechanisms and Mechanics (Cambridge Univ. Press, Cambridge, 1977) ch. II.

bundles of secondary qualities. Philosopher of science Edwin Burtt says of Galileo's writings:

> Man begins to appear for the first time in the history of thought as an irrelevant spectator, and insignificant effect of the great mathematical system which is the substance of reality.[13]

During Newton's time there was a popular view that the mind is a unique but small substance in the brain. Practically all educated people believed this; and there was nothing in Newton's writings to upset this, and everything to support it. Thus, a naive, utterly speculative view of the nature of the mind came to be backed by Newton's great authority. This notion regarded human beings as irrelevant spectators of the world of nature, and it gradually took on the false status of being a scientific fact, rather than an unfounded, metaphysical speculation.

Over the next two centuries, while theology and philosophy apparently made no progress comparable to that of natural science, the spiritual and cognitive elements of nature seemed to wane in significance. Especially during the period 1850-1890, German science in particular was dominated by mechanistic materialism. This expression of

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[13] The Metaphysical Foundations of Modern Physical Science, Edwin A. Burtt (Harcourt, Brace & Co., N.Y., 1927) p. 80.

scientific realism was promoted, for example, by the German physician Ludwig Büchner.[14] According to him, phenomena are inherently mechanical, and everything in the real, independent, objective world--including all animate and inanimate things--reduces to matter. The scientific method is the one true means of discovering the objective laws of nature, and its implementation requires no philosophical speculation. Experience is the crucial test of a scientific theory, and this is purely a matter of observation unmediated by concepts. Mechanistic materialism assumes that sense data cannot be wrong, and they form the unassailable foundation of scientific knowledge.

During the 1870's, the notion of unmediated, conceptually free observation was challenged by Helmholtz. While maintaining a firm realist stance, he recognized that such observation does not play a role in scientific research. Ernst Mach is especially known for his abandonment of the metaphysical baggage that weighed so heavily in mechanistic materialism. According to him, science is a conceptual reflection of facts, which are contents of consciousness given to us by the senses. Only verifiable statements have a place in science, and these must be reducible to statements about sensations. Eventually Mach acknowledged that such a criterion for

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[14] cf. Force and Matter or Principles of the Natural Order of the Universe, Ludwig Büchner, trans. by author (Asher & Co., London, 1884).

verifiability was too narrow, since mathematics, for example, cannot be verified in that way. In his later thinking, he included elements that are not reducible to sensations, but he regarded these as *conventions*, not *a priori* truths.

Maxwell challenged the assumption of mechanistic materialism that the facts "speak for themselves," in the sense that empirical evidence verifies the one true hypothesis that accounts for an event. Purely on mathematical grounds, he posited the existence of electromagnetic waves, and on the basis of his work physical reality came to be conceived as a domain of continuous fields, not mechanically explicable, that are subject to partial differential equations. This was at the time the most profound and fruitful change in physicists' conception of reality since Newton; and it was a major scientific blow to the tenets of mechanistic materialism. Like Newtonian mechanics, Maxwell's theory of electromagnetism predicted a great variety of phenomena, but it failed to explain what electromagnetic waves *are*, just as Newton refrained from hypothesizing about the nature of gravity.

In his treatise entitled *The Value of Science* Poincaré further repudiated one of the fundamental tenets of mechanistic materialism by declaring:

> A reality completely independent of the spirit that conceives it, sees it or feels it, is an impossibility. A world so external as that, even if it existed, would be forever inaccessible to us.[15]

In reviewing the history of physics, Einstein recognized that the natural philosophers of the eighteenth and nineteenth centuries believed on the whole that the fundamental concepts and postulates of physics were induced from experience by logical means. In his view the fallacy of that belief became clear only with the general theory of relativity, which used a foundation quite different from Newtonian theory. Moreover, since multiple hypotheses can account for experience to a large extent, logical deduction alone is insufficient for choosing among them.[16]

There are times when Einstein seems to lean toward an instrumentalist view, when, for example, he acknowledges that scientific theories are "free creations of the human mind" in his statement:

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[15] The Value of Science, H. Poincaré (The Science Press, N.Y., 1907) p. 14.

[16] "On the Method of Theoretical Physics," from Ideas and Opinions, Albert Einstein, based on Mein Weltbild, ed. by Carl Seelig, etc., trans. and revises by Sonya Bangmann (Crown Publishers, Inc., N.Y., 1954) p. 273.

The justification of the system [of physics] rests in the proof of usefulness of the resulting theorems on the basis of sense experience...[17]

But that impression is misleading. Einstein declared that the greatest achievement of Newtonian mechanics lies in the fact that it led beyond the phenomenological representation of Mach. Throughout his life he believed in the possibility of a model of reality, in the sense of a theory which represents things themselves. He was clearly a confirmed realist.

In view of the struggle between Galileo's scientific realism and the Church's insistence upon an instrumentalist view of science, it is interesting to take brief note of Einstein's views on science and religion. As a youth, Einstein experienced something tantamount to a conversion from Judaism to science,[18] but the relation between religion and science was a lifelong concern of his. According to him the ongoing conflict between the two, tracing back to Galileo's time, stems from a misunderstanding of their proper roles. The function of science is to ascertain what is, not what should be; and representatives of science have

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[17] "Physics and Reality" from Out of My Later Years, Albert Einstein (Philosophical Library, N.Y., 1950) p. 96.

[18] cf. "Autobiographical Notes," Albert Einstein, in Albert Einstein: Philosopher-Scientist, ed. Paul A. Schilpp (Open Court, La Salle, Ill., 1969) p. 5.

mistakenly sought to arrive at fundamental value judgments on the basis of the scientific method. In so doing, they unnecessarily set science in opposition to religion. The chief function of religion is to make clear the fundamental ends and value standards of human endeavors. In Einstein's view, advocates of religion err in their belief that scripture can justifiably speak of facts and relationships between facts.[19] By according absolute truthfulness to all the statements recorded in the Bible, for instance, religion intervenes into the sphere of science, thus engendering conflict between the two.

Cardinal Bellarmine insisted that science should avoid intervention into the sphere of theology by abstaining from making statements about reality. If scientists would only keep to the proper function of their discipline--to save the appearances in a manner sufficient for a mathematician--science and religion could peacefully co-exist. In other words, scientists must be instrumentalists, leaving the realist stance to theologians. Einstein turned this judgement on its head: Theologians must be instrumentalists by viewing scriptural statements as means for establishing human values, without attributing them with any factual content concerning the nature of reality. Leave realism to the scientists, and conflict between the two would vanish.

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[19] "Science and Religion" from Out of My Later Years, p. 25.

Einstein went on to claim "that in this materialistic age of ours the serious scientific workers are the only profoundly religious people."[20] Indeed, "you will hardly find one among the profounder sort of scientific minds without a religious feeling of his own."[21] Thus, in his view science totally supplants theology as a means of understanding reality. The encroachment of science into the domain of religion was now complete in terms of factual content. Religion must confine itself to providing value standards, but it must claim no grounds in reality for proposing those standards. In response to Cardinal Bellarmine's statement, "Such a manner of speaking suffices for the mathematician," Einstein might have said, "Such a manner of speaking suffices for the moralist."

The positivist views of Ernst Mach exerted an influence on many scientists, including Einstein, and they made an especially strong impact upon interpretations of quantum mechanics. Mechanistic materialism was one attempt to remove metaphysics from science, but it succeeded only in introducing a particularly naive, unreflective realism into physics. Mach sought to rid science of metaphysics by demanding that each individual statement in a physical theory be empirically verifiable. Logical positivism, which

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[20]"Religion and Science" from Ideas and Opinions, p. 40.

[21]"The Religious Spirit of Science," ibid., p. 40.

was developed during the 1920's, went a step further in its intent to banish metaphysics altogether.

According to logical positivism, only three types of statements are allowable: (1) the logically meaningful (e.g. mathematics), (2) the empirically meaningful (e.g. scientific statements) and (3) proposal statements or commands. Every theoretical statement in physics, for example, must therefore be empirically verifiable; and this implies that every theoretical term (e.g. energy, electron, field) must be definable in observational terms (e.g. measurements or other directly observable physical objects). This insistence is based on the premise that there is a reliable distinction between theoretical and observational terms.

Although Niels Bohr was not a proponent of logical positivism, he too sought a theory of knowledge independent of metaphysics. In his view quantum theory makes no claim to describe or explain any objective quantum world existing independently of systems of measurement.[22] Rather, it is a mathematical formalism that accounts for a wide variety of physical measurements. In his Dialectica Bohr assessed quantum mechanics as follows:

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[22]See Atomic Theory and Description of Nature, N. Bohr (Cambridge Univ. Press, London, 1961).

> The entire formalism is to be considered as a tool for deriving predictions, of definite or statistical character, as regards information obtainable under experimental conditions described in classical terms and specified by means of parameters entering into algebraic or differential equations...These symbols themselves are not susceptible to pictorial interpretation.[23]

Once again we are presented with an ontological view akin to that of Ptolemy: A physical theory is presented as correct not because it explains an independent physical reality, but because it is effective in saving appearances. The school of interpretation of quantum mechanics that arose chiefly from Bohr's perspective may be deemed "ontologically agnostic," and it flourished initially during the heyday of logical positivism.

The debate between instrumentalism and realism, tracing back to Plato and Aristotle, remains unresolved in contemporary physics. Most physicists today show little interest in the ontological foundations of their science. From a materialist perspective, such concerns may be deemed "unproductive," for mathematical theories can be formulated, experiments conducted and technology advanced without

[23]Cited in <u>The Concept of the Positron: A Philosophical Analysis</u>, N.R. Hanson (Cambridge Univ. Press, London, 1963) p. 86.

reference to the real meaning of physical theory. Such an indifference often veils a naive, unreflective realism. Once again a disinterest in metaphysics may result not in abstention from such beliefs, but in unconscious, unintelligent adoption of a particular form of metaphysics.

It is an empirical fact that physical science today exerts a profound and extensive influence not only on our physical environment but upon our way of viewing the world as a whole. There is a prevailing effort to reduce chemistry, biology and psychology to the methods and laws of physics; and this reductionist approach has deeply affected our way of viewing human existence and the universe. Does physical theory describe and explain the real world independent of human experience; or is it simply a conceptual construction created by humans to correlate and predict scientific measurements? Or are there other meaningful ways of understanding the relationship between physics and the natural world? Given the tremendous impact of physics on our daily lives, it seems crucial to give such questions prolonged and careful consideration.

CHAPTER TWELVE:

REALISM

The origins of the realist view concerning physical theory can be traced back to the early thinkers of Greek antiquity, such as Democritus and Aristotle.[1] Copernicus, Kepler and Galileo, three pillars of modern science, likewise take a realist stance as the foundation of physical inquiry; and under their influence, physics has adopted the goal of formulating a single, true theory that will account for all the phenomena of the inanimate universe together. This theory must explain, not merely describe or predict, and in so doing it will place all physical anomalies within an intelligible framework of ideas. In the words of the philosopher of science Norwood Russell Hanson:

> Intelligibility is the goal of physics, the fulfillment of natural philosophy; for natural philosophy is philosophy of matter, a continual

[1]Pythagoras and Plato also took a realist view of the physical world, and their writings form the basis of later mathematical realism such as that adopted by Kepler.

conceptual struggle to fit each new observation of phenomena into a pattern of explanation.[2]

The realists' demand on a physical theory is that it be factual, and the underlying, principal assumption is that the possibility of the facts being described in a certain way constitutes an objective feature of events in the natural world. This is to say that independent of human percepts and concepts there exists an objective world of space, time and configurations of mass and energy, and that this world is humanly intelligible. As science progresses, its theories gradually approximate the one, true, all-embracing theory that will be a perfect fit with reality.

Some realists are confident that science will eventually reach that culmination, while others believe that we will approach that perfect theory only asymptotically, by increasingly accurate approximations.

Einstein, perhaps the foremost realist among modern physicists, holds that belief in a natural world independent of the human mind, yet intelligible to it, lies at the foundation of all natural science. If physical events are independent of human concepts, there must be no relationship between that reality and concepts. But given that assumption, on what grounds can we believe that physical

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[2] Patterns of Discovery: An Inquiry into the Conceptual Foundations of Science, N.R. Hanson (Cambridge Univ. Press, Cambridge, 1958) p. 158.

theory corresponds to such an independent physical reality? In what sense can a concept correspond to, or be associated with, a reality that is unrelated to it, in the sense of being independent of it?

Recognizing the naivety of nineteenth-century realism, Einstein offers no facile response to this problem. In his view "the whole of science is nothing more than a refinement of everyday thinking,"[3] and the same can be said of the realist view of science. In everyday thinking we may have, for example, the thought of a tree falling in a forest. From the past we recall typical complexes of sense experiences of falling trees, and on such bases we form "primary concepts" that are directly connected to those experiences. The corresponding terms are commonly denoted as observational terms. Although our sense experiences do not occur independently of our human senses, we naturally presume that the primary concept of "a falling tree" does refer to something in the independent, objective world. Were this not the case, argues everyday realism, how could orderly, causal, physical events occur in the absence of consciousness of them; and how could different people experience reality in common? The only plausible reason, according to the realist, is that the natural world exists independently of human percepts and concepts; and the

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2 [3]"Physics and Reality" from Out of My Later Years, A. Einstein (Philosophical Library, N.Y., 1950) p. 59.

necessary assumption for human understanding and activity is that that world is intelligible to us.

What is the relationship between the primary concepts of everyday thinking and complexes of sense experiences? Such a question lies outside the domain of physical science, and Einstein maintains that it can be comprehended only intuitively. By means of the intuitive connections between concepts and experiences, however, we can fashion scientific theorems about complexes of sense experiences. The first stage of science, then, contains only primary concepts and theorems relating them.

The second stage contains secondary concepts, associated with theoretical terms, which have only indirect connections with such sensory complexes. Until the close of the nineteenth century, many physicists considered the theoretical term "atom" to be outside the sphere of physics. But in 1905 Einstein presented a paper on Brownian motion which was regarded by the scientific community as a proof of the physical reality of the atom. Similarly, until the experimental work of Rutherford during the early years of this century, the internal structure of the atom seemed purely a matter of metaphysical speculation. But his results unequivocally suggested the existence of an atomic nucleus that is minute in comparison to the dimensions of the atom as a whole.

These secondary concepts and their relations are fewer than the primary concepts, and the primary are derived logically from the secondary. According to Einstein, physics evolves as it formulates ever fewer concepts and relations from which earlier layers of concepts can be derived. In this way science approaches a single unified theory, with the fewest concepts from which all others can be derived.

Nature is thus regarded as a well-formulated puzzle whose solution is found by scientific inquiry. Just as an intricate crossword puzzle finally allows a single, unique array of words, so does the conceptual solution of Nature ultimately allow one unique, unified theorem. In the word puzzle wrong words may temporarily seem to fit, but as the game evolves, their insertion is seen to be erroneous, and with intelligent persistence they are replaced with the correct terms. Similarly, physics may formulate theoretical terms and relations that are temporarily useful and explanatory, without being able to integrate them into a unified theory. But as it progresses, the fallacies of earlier partial theories are recognized, and new or revised theories are conceived that more closely fit the pattern of the one true theory.

Thus, in face of the diversity of conceptually incompatible views that we have encountered concerning the energy of the vacuum, a realist would insist that only one of those theories (or, very possibly, a future theory) will eventually prove to be the one accurate account of this physical reality. For the time being, competing theories within the context of quantum mechanics and outside of it all account for the experimental evidence; but with persistent effort the inadequacies of the false theories will become evident. Only one theory will remain that is entirely internally consistent and precisely accurate in its predictions. And that one will be the true representation of the vacuum as it exists independently in nature.

CHAPTER THIRTEEN:

SOME ASSUMPTIONS OF REALISM

The foregoing discussion mentions a few of the assumptions underlying Western science, and they are so fundamental that physics as we understand it would be inconceivable without them. The initial assumption of the existence of an objective world independent of consciousness and conceptual constructs is a metaphysical belief. Most scientists are unwilling even to consider that it may not be correct, for it is regarded, often implicitly, as an *a priori* truth. Given the history of successive collapses of the *a priori* status of assumptions found in science--e.g. Euclidean geometry, absolute space and time--we have little ground for holding this assumption sacred. Indeed, our everyday experience of the world does lead us to believe in such an independent reality, but if advances in mathematics and physics have taught us anything, it is that common sense assumptions based on sensory experience may be misleading. The curved spacetime of general relativity and equally unimaginable quantum mechanical description of the behavior of atomic entities provide obvious examples.

Is the ontological theory of an independent, objective physical world the only conceivable theory that can save the appearances of everyday and scientific experience? Certainly not. Philosophers in diverse cultures over the past few millennia have devised alternative ontologies that also, with varying degrees of success, account for the facts of experience. Until very recently, Western scientists have shown little inclination to question this metaphysical assumption, though recent insight in quantum mechanics suggest that such inquiry is long overdue.[1]

A second assumption holds that this world, existing independent of human percepts and concepts is, nevertheless, comprehensible in terms of our concepts. If Nature exists independent of our concepts, on what grounds can we believe that our theories can accurately describe and explain natural events? The nineteenth-century belief that Nature herself yields the physical concepts and laws that physicists "discover" is even more implausible. Assuming that physical theories can be true in this sense, in what manner do they represent, or correspond to, Nature herself? Since the birth of modern science, this question has never been answered persuasively.

The third metaphysical assumption is that the universe is like an intricate word puzzle that can finally be solved in one way only. Over the course of history, various theories have laid claim to explaining Nature

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[1]cf. "The Quantum Theory and Reality," Bernard d'Espagnat, Scientific American, Vol. 241, No. 5, Nov., 1979.

comprehensively. Aristotle's physics is a prime example, and its claim of exclusivity and comprehensive accuracy collapsed under the experimental and theoretical scrutiny at the birth of modern science. The world machine theory of reality was touted in the nineteenth century as the one true view and was regarded as essentially complete, barring a few minor "clouds on the horizon," such as the ultraviolet catastrophe. Closer scrutiny of those apparently minor anomalies initiated bold new ways of viewing reality, and these raised a vast number of questions that never occurred to earlier physicists. Now as we draw to the close of the twentieth century, highly respected physicists are encouraging the public once again to believe that the one true unified theory, which accounts for all natural phenomena, is at hand. Only a few pieces in the puzzle, such as a quantum theory of gravity, are needed, and physics will have been brought to its culmination.

Such a crusade on college campuses is an effective means to inspire students to devote their lives to this ultimate quest, and the promise to the public of "victory in our time" is useful in raising funds for scientific research. Moreover, the sincere faith of most advocates of this view seems unquestionable. However, as mentioned previously, few of those true believers appear to have seriously confronted the fact that multiple hypotheses have always been able to account for any given body of data.

This is as true now as it was at the time of Ptolemy. Indeed the types of theories change as more sophisticated means of experimentation are deployed, but the presence of variety persists.

Given the history of diversity in physics, we must consider the possibility that multiple theories could equally account for <u>all possible experience</u>. Let us first set aside the problem of identifying any set of facts about the physical world as complete. Now consider a time, possibly in the near future, when scientists will devise a grand unified theory that accounts for all known forces in the universe. Such a theory will be based upon not only the experimental facts, but the metaphysical assumptions of its creators. This being the case, it seems perfectly reasonable to expect that a competing grand unified theory could be devised that equally accounts for all the facts, while be based on different metaphysical assumptions. In principle, there is no limit to the variety of such theories that might be formulated; and they could all be conceptually incompatible. Each would vary depending on the diversity of metaphysical assumptions that precede scientific inquiry.

Now let us address the question of identifying any body of facts as complete. It is true that some noted scientists believe that a unified theory accounting for all of reality is close at hand, but to believe this requires an extraordinary leap of faith. On what grounds shall we believe that fundamentally new modes of experimentation will not be deployed that would shed light on a new range of anomalous phenomena? A unified theory may explain all the facts available when it is formulated, but who is to say that human ingenuity cannot discover a new range of facts? The scientists who evangelize for the immanent grand unified theory today are not more intelligent or respected by their peers than the physicists of the previous century who regarded physics as essentially complete. It seems that metaphysical naivety may once again be leading scientists and their devotees into an illusion of omniscience.

Another common assumption among physical scientists is that everything is made of atoms; and Nobel prize-winning physicist Richard Feynman goes on to insist that "there is nothing that living things do that cannot be understood from the point of view that they are made of atoms acting according to the laws of physics."[2] A closely related principle is the conservation of energy. It is interesting to note Feynman's assertion that the conservation of energy is a mathematical principle, not a description of a mechanism , or anything concrete. He goes on to state: "It is important to realize that in physics today, we have no

[2] The Feynman Lectures on Physics, R.P. Feynman, R.B. Leighton, M. Sands (Addison-Wesley Pub. Co., Reading, Mass., 1963) p. 1-9.

knowledge of what energy *is*."[3] If, as Feynman seems to suggest, energy is an abstraction, we may wonder whether it is purely a conceptual construct, rather than an independent physical reality.

What implications would this conclusion have concerning the nature of matter? Einstein and Infeld summarize one of the foremost discoveries of modern physics: "According to the theory of relativity, there is no essential distinction between mass and energy. Energy has mass and mass represents energy."[4] Thus, if energy is simply an abstract concept, a mathematical principle and not an objective physical reality, what then shall we conclude concerning the physical reality of atoms?

In 1957, the philosopher of science Hans Reichenbach expressed the view of many physicists when he declared:

> The atomic character of matter belongs to the most certain facts of our present knowledge...we can speak of the existence of atoms with the same certainty as the existence of stars.[5]

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[3] *ibid.*, p. 4-2.

[4] *The Evolution of Physics*, A. Einstein and L. Infeld (A Touchstone Book, Simon & Schuster, N.Y., 1966) p. 197.

[5] Cited in *Quantum Reality: Beyond the New Physics*, N. Herbert (Anchor Press/Doubleday, Garden City, N.Y., 1985) p. 12.

What is the nature of this certain knowledge of atoms? French physicist Bernard d'Espagnat maintains that atoms, as well as all other knowable entities are mere properties of nothing other than space or space-time.[6] Physicist John Gribbin points out, however, that while quantum mechanics tells us a lot about material particles, it tells us scarcely anything at all about empty space.[7] And astronomer Edward Harrison points out a further complexity of the situation when he writes: "There are countless possible spaces with their own geometries, and all are equally valid and self-consistent."[8] If each of these countless possible spaces equally accounts for phenomena, how are we to choose among them?

Gribbin proposes another view on the ontological status of atoms and sub-atomic particles when he says:

> If we cannot say what a particle does when we are not looking at it, neither can we say if it exists when we are not looking at it, and it is reasonable to claim that nuclei and positrons did

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[6] In Search of Reality, Bernard d'Espagnat (Springer-Verlag, N.Y., 1981) p. 84.

[7] In Search of Schrödinger's Cat: Quantum Physics and Reality, John Gribbin (Bantam Books, N.Y., 1984) p. 259.

[8] Cosmology: The Science of the Universe, Edward R. Harrison (Cambridge Univ. Press, N.Y., 1981) p. 148.

> not exist prior to the twentieth century, because nobody before 1900 ever saw one.[9]

American physicist Henry Stapp posits yet another view concerning particles of matter:

> An elementary particle is not an independently existing unanalysable entity. It is, in essence, a set of relationships that reach outward to other things.[10]

Werner Heisenberg informs us that "atoms are not things,"[11] and Niels Bohr makes the yet broader statement that "there is no quantum world, there is only an abstract quantum description."[12] Thus, before we take comfort in the thought that the reality of atoms is as certain as that of stars, we must reflect that much of our knowledge of the heavens, with its neutron stars, white dwarfs and so on, is based on quantum theory. And here one of the principle architects of that theory denies that it describes an independent physical reality, while another remains ontologically agnostic. In

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[9] ibid., p. 162.

[10] Cited in Superforce, Paul Davies (Simon and Schuster, Inc., N.Y., 1985) p. 49.

[11] Cited in Quantum Reality: Beyond the New Physics, p. 22.

[12] ibid, p. 22.

short, while physicists are generally agreed that energy is conserved and that matter is composed of atoms, no one seems to know what energy is, and there is fundamental diversity of opinion as to the ontological status of atoms.

There are a number of secondary assumptions that underlie branches of science and that are indispensable to them. A central belief is that the laws of nature are in themselves written in the language of mathematics. This view will be examined in some detail in a later chapter. Modern science is also based on the medieval insistence on simplicity and beauty in the formulation of physical theories. Once again, this predilection precedes scientific inquiry. If nature is in fact complex and does not conform to our present concept of beauty, physicists apparently do not want to know about it. Theories that fail to conform to those principles are therefore unlikely to be formulated, or in the case of their appearance, they are unlikely to be promoted. Some scientists may even adhere to those assumptions despite physical evidence to the contrary. Paul Dirac, for instance, commented: "It is more important to have beauty in one's equations than to have them fit experiment."[13] Such an insistence challenges experimental

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[13] Cited in Superforce, Paul Davies (Simon and Schuster, N.Y., 1985) p. 54.

physicists to confirm what must be true. In other words, the appearances must save the theory.

Turning now to classical mechanics, we find that the notion of a "material point" is a fundamental assumption. Our sensory experience of physical phenomena, however, does not allow them to be treated as material points, so mechanics is presented with the theoretical challenge: How can we imagine an object to be built up out of material points, and what forces must we assume as acting among them?[14] Thus, given this assumption, which precedes the formulation of classical mechanics, it is apparent that this branch of physics must inevitably lead us to an atomistic construction of matter.

In contrast to mechanics, electromagnetic theory was founded on such notions as waves, fields and the ether. Quantum theory takes as its starting point the concepts of packets of energy and wave pulses; and general relativity rests on the notion of gravitational fields. Classical physics could not fully unify mechanics and electromagnetism, just as contemporary physics has had little success in unifying quantum mechanics and general relativity. Moreover, quantum mechanics remains plagued with the dilemma that its experiments are described in terms of classical physics, and its tenets proclaim that those

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[14] "Physics and Reality," from Out of My Later Years, A. Einstein (Philosophical Library, N.Y., 1950) p. 72.

concepts do not fit nature accurately. As N.R. Hanson points out: "There is no ultimate logical connexion between the languages of classical physics and quantum physics, any more than between a sense-datum language and a material object language."[15] Indeed, the languages formulated from such diverse initial premises turn out to yield logical differences throughout. It then becomes untenable to regard classical theories as "limiting cases" of contemporary physics.

Twentieth-century physics has certainly retained many of the theoretical terms from the classical era. The concept of elementary particles, for example, has persisted over the centuries, but it is crucial to recognize the profound changes it has undergone. Even within this century the same terms have been used for starkly different objects. When the electron was first discovered, for example, it was regarded as an independent particle of matter bearing negative electric charge. Soon a model was created in which it was seen orbiting about the atomic nucleus, like a planet around the sun. Then it was recognized as bearing both attributes of a particle and of a wave. But particles and waves had always been regarded as mutually exclusive types of entities. The "planetary model" of the electron could now be seen as a partial, heuristic device at best. As a

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[15] Patterns of Discovery, N.R. Hanson (Cambridge Univ. Press, Cambridge, 1958) p. 153.

picture of the physical reality of the electron and the nucleus, it is misleading, despite the fact that elementary physics textbooks usually leave students with such a concept of the atom. Following the advent of Heisenberg's uncertainty principle, the electron has been regarded variously as a mathematical abstraction and as a physical probability distribution. In quantum field theory, it, like other particles, is conceived as an elementary quantum of excitation of a field.

From this brief account it is evident that earlier and later concepts of the electron bear very little in common. Yet at no point have physicists been inclined to discard the electron altogether. The notion has been a "survivor," undergoing major mutations as it has been subject to the changing climates of physical inquiry. Indeed, but for the continuous use of the word "electron," we would be hard pressed to guess that physicists were modifying one concept rather than abandoning the old and replacing it with the new. Will the concept of particles survive in future developments of physics? Einstein speculates that in the foundations of any consistent field theory that may eventually appear, there will be no concept concerning particles in addition to the concept of the field.[16]

The concept of the atom was prevalent in nineteenth-century physics and, with great modification, it has

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[16] "Physics and Reality," from Out of My Later Years, p. 78.

survived into contemporary physics. The concept of the ether was even more ingrained in classical theory, but now physics textbooks inform students that the ether never had physical reality. The concept is relegated to the status of a naive, mistaken assumption concerning the nature of electric and magnetic fields, and Einstein is attributed with the achievement of demonstrating this fallacy. In fact, as we have seen, Einstein insisted that the concept of the ether be modified, not discarded.[17] But the momentum of physical thought swept away the ether, as if relieved to dispense with a problem that had been a constant, unalleviated source of frustration. The ether has now been replaced in general relativity with spacetime that has structure and is subject to curvature. In quantum field theory the ether is replaced with the vacuum, which contains at least virtual energy, which bears a structure, is subject to polarization and exerts observable influences on particles that are introduced into it.

Did not elementary particles such as the electron undergo modifications at least as profound as those of empty space? Why did the electron survive, while the ether did not? The simple answer is that physicists simply decided that the meaning of the term "ether" would be frozen in its classical context; whereas "electron" was allowed to adapt

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[17] cf. "Ether and the Theory of Relativity," from Sidelights on Relativity, A. Einstein, trans. G.B. Jeffrey and W. Perrett (Dover Publications, Inc. N.Y., 1983).

to a sequence of changing theories. This decision was not made on the basis of experimental evidence nor was it due to strictly scientific, theoretical argument. Rather, it was a matter of terminological preference stemming from non-physical considerations and biases. In light of this fact, we may well wonder if other scientific dinosaurs such as caloric and phlogiston might not have survived if they had been allowed to adapt to new evidence and theories. Were they any more intrinsically doomed to extinction than the electron? Once again we are faced with a matter of preference, the origins of which lie outside the strict domains of science.

CHAPTER FOURTEEN:

THEORY AND DISCOVERY IN PHYSICAL SCIENCE

The history of physics shows that certain concepts have taken on the status of indispensable principles, the foremost of these being the conservation of energy. As we have seen, this principle arose initially from a metaphysical assumption that predated hard scientific evidence to support it. But as it was gradually adopted by physicists, empirical support was found, and it attained the status of a scientific law. As research continued, the evidence necessitated the recognition of new types of energy that would balance the ledger in certain conversion processes. In the present century, energy came to be regarded as interchangeable with mass; and to preserve the conservation principle on the atomic level, physicists have posited the existence of a whole menagerie of particles. The conservation of energy is a prime example of a scientific truth that was early on established by experiment, then became so indispensable to physics that violations of it are considered unthinkable.

An examination of the process of scientific inquiry makes it evident that physical theories are not simply derived inductively from experience, as was believed by naive realists of the last century. As Einstein commented to Heisenberg:

> But on principle, it is quite wrong to try founding a theory on observable magnitudes alone. In reality the very opposite happens. It is the theory which decides what we can observe.[1]

Niels Bohr expressed a similar insight when he wrote:

> As our knowledge becomes wider, we must always be prepared, therefore, to expect alterations in the points of view best suited for the ordering of our experience. In this connection we must remember, above all, that, as a matter of course, all new experience makes its appearance within the frame of our customary points of view and forms of perception.[2]

Newton's claim of feigning no hypotheses that are not direct results of experience turns out to be no more realistic than his assumed absolute space and time.

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[1]Cited in Physics and Beyond: Encounters and Conversations, Werner Heisenberg (Harper and Row, N.Y. 1971) p. 63.

[2]Atomic Theory and the Description of Nature, N. Bohr (Cambridge Univ. Press, London, 1961) p. 1.

Whether in everyday experience or while engaged in scientific research, we are presented with far more experimental data than we are able to assimilate and organize. We are thus compelled to sift through the contents of experience, distinguishing the relevant and meaningful from mere "noise." By what criteria do we make this distinction? It cannot possibly be made from the side of the experiential data; rather, it is made on the basis of our preconceived, and often unconscious, ideas and theories. In this way the theory allows us to observe certain data as meaningful, while screening out whatever is left over.

In the words of Peter Medawar, a Nobel prize laureate in medicine:

> The teacher has forgotten, and the student himself will soon forget, that what he sees conveys no information until he knows beforehand the kind of things he is expected to see.[3]

This insight is not a new one, but as Medawar points out, it is easily ignored. Nietzsche generalizes on this same theme when he writes that "everything of which we become conscious

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[3] Pluto's Republic, Peter Medawar (Oxford Univ. Press, N.Y., 1984) p. 117.

is arranged, simplified, schematized, interpreted through and through...".[4]

History presents a number of flagrant examples of an accepted theory preventing the observation, or ascertainment, of a natural event that is later retrieved by a new theory. One of the most renowned cases concerns a supernova explosion in the year 1054. For twenty-three days this star shone as brightly as Venus at night and was visible even by daylight. It faded from view altogether after eighty nights short of two years.

During that era, astronomers around the world took a keen interest in observing the night skies, but they did so with different preconceived ideas. The astronomers of Europe were committed to the ancient Greek theory that heavenly bodies are immutable, and none of them left surviving accounts of having witnessed this unallowed phenomenon. Here is another case of the phenomena having to "save the theory," which they could do only by being ignored altogether. Chinese astronomers, on the other hand, were not subject to that Greek assumption, and they left numerous accounts of this startling event. By the sixteenth century the European commitment to the writings of Greek antiquity had begun to be challenged. Thus, when another supernova

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[4] The Will to Power, Friedrich Nietzsche, trans. by Walter Kaufmann and R.J. Hollingdale (Random House, N.Y., 1967) pp. 263-264.

appeared in 1572, Tycho Brahe studied it and concluded that stars are subject to generation and decay.

A more recent example entails the discovery of the positron.[5] Until the early 1930's, physicists were committed to the belief that the fundamental unit of positive charge, or electricity, could only be associated with the proton. Prior to 1930, several microphysicists "saw," but did not "observe" tracks of the positron, an elementary particle similar to an electron but for its positive, instead of negative, charge. Those tracks were seen as spurious and dismissed as "dirt effects." In 1931 Paul Dirac conducted theoretical research that suggested that empirical evidence should be attainable. In the following year the experimental physicist Carl D. Anderson challenged prevailing opinion by identifying the positron tracks, apparently without knowing of Dirac's theoretical justification. Finally in 1933 two other physicists discovered that the Anderson particle and the Dirac particle were identical.

It seems then that innovators in science are frequently those with sufficient courage to challenge widespread assumptions, enabling them to observe phenomena that were concealed from their peers by the veils of preconceived ideas. N.R. Hanson comments:

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[5] See The Concept of the Positron, N.R. Hanson (Cambridge Univ. Press, London, 1963).

> The paradigm observer is not the man who sees and reports what all normal observers see and report, but the man who sees in familiar objects what no one else has seen before.[6]

If theory largely predetermines which phenomena can make an imprint on human intelligence, it follows that scientific observation must also be influenced by the language in which a theory is expressed. We may then expect that people using such different languages as English, Hopi[7], and Tibetan might have difficulty in apprehending the same facts. Since we can hardly believe that Nature has a bias for expressing herself in European languages, we must conclude that our view of reality is inescapably a European view. While our languages and theories have unveiled certain facets of reality, it can hardly be denied that they have concealed others. Moreover, it seems highly probable that non-European inquiries into Nature have shed light on phenomena that remain hidden to us.

Many physicists shy away from seeking to describe or explain physical reality in any words at all. Prose

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[6] Patterns of Discovery, N.R. Hanson (Cambridge Univ. Press, Cambridge, 1958) p. 30.

[7] See Language, Thought and Reality: Selected Writings of Benjamin Lee Whorf, ed. by John B. Carroll (M.I.T. Press, Cambridge, Mass., 1966).

accounts are subject to the vagaries of human language, grammar and logic, and such thinkers are concerned with grasping reality as it exists independently of human thought and experience. On these grounds they confine themselves to quantitative data and mathematical analysis. The goal of physics is still a grand unified theory, but it is sufficient that it remain a purely mathematical theory, devoid of verbal interpretation. The assumption here is that, as Einstein claimed, Nature is the realization of mathematical ideas, and that these ideas, while accessible to the human mind, find their source in Reality.

The claim that the Ultimately Real speaks in one unique language is not found in physics alone. Traditional Hebrew belief holds that the Creator and Ruler of the Universe expresses Himself in the sacred language of Hebrew. Hindu faith maintains that God speaks in Sanskrit, and that this divine language pervades the whole of Nature. While all three languages--mathematics, Hebrew and Sanskrit--purportedly originate from a transcendent source of Reality, they are all accessible to the human mind; and in this way human intelligence taps into independent, objective Reality. Scientists may assert that unlike the grammar of spoken languages, the rules of mathematics are infallible and independent of the human mind. Investigation into the foundations of mathematics, however, seriously questions that assumption.[8]

The belief that mathematical laws are intrinsic to an independent physical reality tends to overlook the fact that the quantitative data on which those laws are based invariably arise from interactions between measuring devices and measured quantities. In the words of Werner Heisenberg: "What we observe is not nature in itself but nature exposed to our method of questioning."[9] When we question nature with quantitative instruments, we obtain quantitative results which, upon being sifted through the screen of prevailing theory, often conform to mathematical laws.

Do either the quantitative data or the mathematical laws inform us of nature independent of our experimental and theoretical modes of inquiry? Einstein would have replied in the affirmative, and he formulated a criterion of independent physical reality as follows:

> If, without in any way disturbing a system, we can predict with certainty the value of a physical

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[8] A more detailed critique of mathematical realism is presented in Chapter XIX. See also Descartes' Dream: The World According to Mathematics, Philip J. Davis and Reuben Hersh (Harcourt Brace Jovanovich, N.Y., 1986).

[9] Physics and Philosophy: The Revolution in Modern Science, W. Heisenberg (Harper and Row, N.Y., 1962) p. 58.

quantity, then there exists an element of physical reality corresponding to this physical quantity.[10]

In reference to quantum mechanics, Bohr countered that "the procedure of measurements has an essential influence on the conditions of which the very definition of the physical quantities in question rests."[11] More broadly speaking, to know what we are measuring, we must know the function of our measuring device.[12] Is it, for example, a voltmeter or an ammeter? The quantity obtained takes on a physical status only upon its being interpreted within a specific theoretical context. A meter reading may indicate a certain quantity, but that number is not self-interpreting. To what physical reality does it correspond? This can be answered only from the context of a theory, and diverse theories may well offer different explanations of the nature of the measured event.

In short, what Einstein calls a physical quantity is simply a number, and if it does correspond to a physical reality, that quantity alone yields no suggestion of what that reality might be. It is up to us to "make sense" of

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[10] A. Einstein, B. Poldolsky, N. Rosen, Phys. Rev., 47, (1935) 777.

[11] N. Bohr, Nature, 136, (1935) 65.

[12] Symmetries and Reflections: Scientific Essays of Eugene P. Wigner, (Indiana Univ. Press, Bloomingtor, 1967) p. 197.

it, and we do so on the basis of our human experience and concepts. Secondly, any such quantity that is measured either by disturbing or not disturbing a system is the result of an interaction of the measuring device and the measured event. Recalling Heisenberg's similar comment, it is a measure not of nature itself, but nature exposed to our method of detection.

To draw a parallel, according to the materialist view of nature, the colors that we perceive with our visual faculties do not exist in independent physical reality. Objectively there are only particles of mass-energy in motion, and when certain of these particles, called photons, interact with our visual organs, colors are subjectively experienced. Our visual faculties are of such a design that when they interact with photons, visual sensations of color occur; but those colors does not exist in the photons themselves. If those photons interact with our skin, a sensation of warmth may be produced, but that warmth is no more intrinsic to the photons than are the colors that we perceive.

Now physicists bring to bear on photons non-organic apparatuses of detection, and when these interact with photons, quantities are produced. When we direct our visual gaze at photons, it is a foregone conclusion that if we detect anything, it will be colors. When we direct a quantitative measuring device at photons, it is a foregone conclusion that if it detects anything, it will be quantities. Neither mode of observation gives us information about photons existing independent of all methods of detection. Thus, the realist view that quantities are intrinsic to physical reality, whereas colors are not, is based on an unfounded metaphysical assumption that traces back to Democritus.

Thus, the assumption of the independent physical reality of a measured quantity is as questionable as the independent status that we attribute to a physical entity (e.g. a photon) associated with that quantity. The belief in mathematics as an intrinsic attribute of reality in itself is akin to the belief that the contents of a physical theory are independent elements of nature. Both assertions ignore the fundamentally participatory nature of scientific research.

This point is well illustrated in the case of the Casimir effect. Recall that within the context of quantum electrodynamics, Casimir calculated that a minute attractive force should be exerted between two walls of a cavity. Is this a zero-point force originating from the vacuum as conceived in quantum field theory? Or do fields play no role in this force, as suggested by Schwinger? Is the experimental effect due to the semi-classical, retarded London-van der Waal's force, or to classical, randomly oscillating electromagnetic radiation, as conceived by

Boyer? Experimental evidence has thus far proven incapable of deciding such questions about the physical reality of the situation, and it is questionable whether it ever will.

Casimir predicted a force of a definite magnitude, and this force varies inversely with the fourth power of the separation of the walls of the cavity. But neither the force constant nor the fact that it is an inverse fourth-power force exist independently in the nature of the vacuum itself. Such properties appear in the context of a given system of measurement, but we have no empirical grounds for believing that they have any existence independent of such a context.

CHAPTER FIFTEEN:

THE HYPOTHETICAL REALITIES OF PHYSICS

In our investigations of the physical world we employ specific instruments, most of which were designed with a physical theory, such as electromagnetism, in mind. Our basic experimental data are produced by interactions between such devices and physical events. Had we used radically different modes of observation--including non-quantitative means--our experimental results would have been different. With the empirical data in hand, we are faced with the challenge of interpreting them. The standard procedure in atomic physics, as well as various other branches of science, is known as retroduction.[1] In this process we regard a body of empirical evidence with a specific theory in mind. Much of the evidence is accounted for in a familiar way by the theory, but now let us imagine that some surprising phenomenon is observed. Wishing to explain that phenomenon in terms of our theory, we propose that it would be explicable if a physical entity--e.g. a new particle with attributes determined by the evidence--existed. We then conclude that the proposed particle exists. N.R. Hanson

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[1] Patterns of Discovery, N.R. Hanson (Cambridge Univ. Press, Cambridge, 1958) p. 86.

insists that we should accept such a physical concept, even if it is nothing more than an "ingenious mathematical combination of physically distinct parameters," for if we do, "a comprehensive and systematic explanation of those diverse and apparently incompatible microphysical phenomena will follow as a matter of course."[2]

Retroduction is without question a useful procedure for explaining and predicting observed phenomena, but we are concerned here with the question as to whether it informs us of the nature of independent physical entities. In other words, is it a means of discovering pre-existing entities existing independently of our mode of inquiry, or does it simply allow us to create hypothetical concepts that are useful for explaining observed phenomena? If we adopt the former view, we thereby assume that micro-entities forever hidden from perception can be discovered by means of inference. Such inference identifies them on the basis of the observable evidence that they help to produce. That evidence might be traces in a cloud chamber, for example, produced by interactions of subatomic particles with the medium of the chamber.

Such a process of identification entails discovering the defining characteristics of the subatomic entity in question. Let us call that entity a dreamon. Now a dreamon may be defined in terms of the macroscopic effects that are

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[2] ibid., p. 109.

produced when it interacts with a certain measuring device. When we then declare that a dreamon exists, we are simply stating that something that helps cause those effects exists. That may be a useful shorthand device for organizing data, but the tautological nature of the claim divorces it from any statement about an independent physical reality. This can hardly be called a discovery.

The other option is to define a dreamon in terms of its own intrinsic characteristics such as charge, mass and spin. As before, we are presented with certain observable effects that are produced by the interaction of some physical entity with our system of measurement. Following the retroductive procedure, we hypothesize that if there were a particle with the defining characteristics of a dreamon, it would produce the observed effects. Now in order to establish that a dreamon actually has a physical reality independent of our system of measurement and theoretical constructs, we would have to demonstrate that only that entity could have interacted with the system to produce those results.

In the macroworld it is frequently possible to infer the presence of a cause from its effect. Combustion, for example, can be inferred from smoke. Here lies the difference: In the macroworld we are able perceive combustion producing smoke, whereas we have never been able to make such a direct observation of subatomic entities. Thus, microphysics may be likened to a detective story in which we obtain only clues, but never an eyewitness of the crime or a confession from the criminal himself.[3] We obtain only circumstantial evidence that leaves micro-objects with nothing more than an "as if" reality; for physics has never been able to demonstrate that its theoretical concepts uniquely account for the experimental facts.

Recognizing the uncertainty of scientific explanations, C.S. Pierce commented that "the conclusions of science make no pretence to being more than probable."[4] Particularly in light of earlier revisions of physical theory, some physicists teach their students that the contemporary notions of electromagnetic waves, fields, subatomic particles and so on are only probably true. Having admitted this at the outset, such concepts are then used as if they do correspond to physical reality. It is as if the judge pronounces the evidence to be merely circumstantial, then proceeds to sentence the suspect to prison.

Another reason for attributing only "probable status" to scientific explanations is that incompatible theories are sometimes employed for the same subject matter. Light, for example, (as well as electrons and other subatomic particles) is described in one context as a wave and in

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[3]This analogy is drawn from a lecture on the foundations of physics by the theoretical physicist Hanspeter Seipp at Amherst College, April 23, 1986.

[4]Cited in <u>Pluto's Republic</u>, P. Medawar (Oxford Univ. Press, N.Y., 1984) p. 120.

another as a particle. However, there can be no intrinsically real physical entity that is both a wave and a particle, for the defining characteristics of those two phenomena are mutually incompatible. A "probable realist" justifies this by claiming that such theories are a temporary makeshift: They are to be abandoned when an internally consistent theory is developed, that is more comprehensive than either of the previous ones. Indeed, such a realist may acknowledge that all theories are corrigible, and that future theories will only better approximate the one true explanation of nature, without actually reaching that idea.

The philosopher of science Karl Popper expresses a similar theme in his assertion that scientific theories are subject only to empirical refutation but never unequivocal verification. This statement, however, is only partially true. Twentieth-century experiments have refuted the existence of the ether, but only as it is conceived in the context of physical theories of the nineteenth century (and earlier). One may discard one physical concept altogether in favor of another, and when fundamental concepts are changed we tend to speak of "revolutions" in physics. In making such shifts we may fail to recognize that the supposedly antiquated theories could have been modified in an ad hoc way to account for recent discoveries. Empirical facts by themselves do not discard older theories. This comes about only with the addition of metaphysical principles such as the demand for simplicity, beauty and so on.

"Probable realism" assumes the existence of an independent physical reality and proposes at any point in history that contemporary physical theories are "probably accurate." Thus, in Aristotle's time, his terrestrial and celestial physics was probably accurate; in the seventeenth century absolute space and time probably existed; two centuries later the ether was probably a reality; and in the first decade of this century electrons were probably simple particles with definite, simultaneous velocity and position. But from the perspective of the late twentieth century, none of those statements are probable; they are all false.

Probable realism also seems to assume that physical theory progresses through history on a unified front; it is like a line that asymptotically approaches the axis of truth. As we have seen, however, throughout the history of physics, prominent scientists have always differed in their interpretations of empirical data and mathematical formalisms. Newton and Leibniz fundamentally differed in their views of the nature of force, matter and space; and such dissention continues today in competing interpretations of quantum mechanics. Thus, at any point in history, which among conceptually incompatible theories is to be regarded as "probable"? In the future a mathematical formalism may be devised that provides the structure of a grand unified theory. We may expect that this formalism and the associated empirical evidence will also be subject to diverse, incompatible interpretations, or physical theories. The extent of their diversity will be confined only by the limitations of the imaginations of those who create them. Which among such a selection should be deemed "probable"?

At any point in history we may simply declare that a certain physical theory is a final, true representation of physical reality. Such an unequivocal assertion would suggest a profound lack of intelligent reflection on the philosophical foundations and history of physics. A more cautious stance is to maintain that a theory is at best probable, but the content and justification for this statement seem to dissolve under scrutiny. A third realist position is to assume that the physical world does exist in its own right, but that science has no means for ascertaining whether its theories are correct or even probable. This is tantamount to the belief that the world is real but unknowable, and it hardly provides any incentive for scientific research, apart from the satisfaction of the game and the usefulness of the ensuing technology.

CHAPTER SIXTEEN:

QUANTUM REALITY

Some of the metaphysical assumptions underlying physics, such as the realist view, have been called into question in this century due to insights into quantum mechanics. Is the world governed by strict causality on the atomic level, as assumed in classical physics? Do elementary particles exist in their own right, independent of the system of measurement? Do they have definite, simultaneous velocity and position? Can the physicist explore the fundamental components of physical reality as they exist on their own, or must the role of the experimenter and experimental apparatus always be taken into account?

Experimental results in quantum mechanics have been instrumental in helping to raise such questions, but they have not been able to provide answers that are universally accepted by the physics community. The wave/particle nature of micro-entities is a major source of wonderment. When the concept of an electron was first devised, empirical evidence plainly indicated that it is a particle. But this conclusion was soon followed by theoretical and experimental grounds for concluding that it has wave properties. A particle has a definite size and location, and it either penetrates other objects or bounces off of them like a bullet. A wave in three dimensions, on the other hand, spreads out in space. Any initial size quickly expands so that there are no clear-cut dimensions. Such a wave therefore has no simple, point-like location, and one wave may pass through another with no sustained effect. In certain situations waves can interact in such a way that they set up interference patterns.

In short, particles and waves seem to be fundamentally different types of entities. Thus, no one object can be both a particle and a wave, any more than a single object can be both a bullet and a ripple. Yet electrons, like other subatomic entities, display both particle and wave characteristics, and this is one of the central enigmas of quantum mechanics.

The enigmatic quality of this discovery may be attributed to an apparently innate tendency of the human mind known as <u>reification</u>. The initial system of detection in which electrons were discovered yielded results that we attribute to point-like objects. On the basis of everyday experience, physicists assumed that the electron is a particle, regardless of any system of measurement to which it is subject. Thus, the evidence for its particle nature was reified; that is, it was regarded as a real object existing independently of experiment and theory. It was assumed to be the intrinsic nature of the electron. But when the electron is subject to a different type of measurement system, the interaction between the two suggests the presence of a wave. When we proceed to reify the wave nature of the electron, we encounter a paradox; for it must now intrinsically be both a particle and a wave, and that is impossible.

Let us take another physical entity that is detected by different experiments. When the radiation from the sun interacts with our visual faculties, sensations of brightness and color are produced. On this basis, we tend to reify the sun's radiation, believing that those qualities are intrinsic to it. We forget that they are produced only in interaction with our own faculties. The eyes and visual consciousness are thus naively regarded more as clear, passive windows through which the bright yellow light of the sun passes. Their active role in co-producing such visual sensations is ignored.

If our initial experience of the radiation of the sun were only visual, we might simply conclude that it has the intrinsic nature of bright yellow light. Let us imagine that we then experience the interaction of the sun's radiation with our skin. This interaction produces sensations of heat, and we are then tempted to reify this quality as well: This radiation is intrinsically of the nature of heat. But now we encounter a dilemma: Bright yellow color is as fundamentally different from heat. How then can a single object be both color and heat? The problem arises not from a mystical nature of the sun's radiation, but from the naive tendency of reification.[1]

Democritus partially recognized this problem over two millennia ago. He declared that such properties as color, heat, and taste do not exist in the physical objects themselves, but only in their interactions with the senses. What is the intrinsic nature of the physical world? It is composed of space in which atoms with intrinsic size and shape move about with intrinsic velocities. Here is the metaphysical basis of mechanistic materialism, and it was adopted with only minor variations by Galileo and classical mechanics.

This residual reification was challenged by relativity theory and more so by quantum theory. Until then the role of the observer and the system of measurement was largely ignored. The scientists' instruments of observation were regarded as clear, passive windows into which the intrinsic

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[1] Classical physics does provide a model that encompasses both effects with no conceptual difficulty, but it is based on an absolute, Cartesian dichotomy between subjective sensory experience and the physical world presumably existing independent of experience. Thus, from this perspective one could say that a man who is ignorant of physics knows nothing of light or heat, even though his visual and tactile senses are functioning properly. Here is a case of the Cartesian disparity between sensory experience and the real physical world: Abstract theories about physical noumena (e.g. electromagnetic fields and the kinetic energy of atoms) embody true knowledge of nature; while reliable subjective experience is reduced to such acts as reading the quantitative data from scientific instruments.

quantities of nature pass; and the scientists' minds received nature's laws inductively from experience. Such a naive view is no longer tenable. Quantum mechanics presents us with objects that are seen as both waves and particles, but is this any more remarkable than detecting the sun's radiation as both color and heat?[2]

An insistence on reifying intrinsic elements of the microworld leads to a myriad of logical inconsistencies, and these have been touted as being suggestive of the mystical nature of the world of quantum mechanics. But parallels in everyday experience indicate that if electrons are to be reified as being intrinsically particles and waves, we may as well reify solar radiation as both color and heat. Interpretations of quantum theory are often counterintuitive and logically bizarre. Such traits have led some thinkers to draw parallels with oriental mysticism, even to the extent of equating various insights of these diverse disciplines.[3] Before leaping to such conclusions, it would be worth our while to examine some of the sources of this mystification in modern physics.

Quantum mechanics has enjoyed tremendous success in mathematically accounting for the wave/particle nature of

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[2]The fact that the frequencies of visual light and heat are different is not germane to this argument.

[3]cf. The Tao of Physics, Fritjof Capra (Shambhala, Berkeley, Calif., 1975) and The Dancing Wu Li Masters, Gary Zukav (Marrow, N.Y., 1979).

the electron, but this in no way solves the conceptual problem of the physical nature of the electron. The theory is inconsistent, for it describes manifestly non-classical objects, but nevertheless is based on measurements in which electrons are regarded as classical entities. The problem may be dismissed on the grounds that classical physics is merely an approximation of reality in which quantum effects are too small to be seen. However, this argument is circular, for the subtle concepts of quantum mechanics are formulated with gross, classical concepts. The necessity of classical ideas in quantum theory cannot be resolved with the fact that those ideas are not applicable in representing the quantum world.

Another inconsistency of quantum mechanics occurs in the concept of subatomic entities such as the electron. Due to Heisenberg's uncertainty principle, many physicists now believe that the electron, for example, does not simultaneously bear definite location and velocity. Experimentally, insofar as precise measurement is taken of its velocity, knowledge of its location is precluded and vice versa. This fact seems to be inherent in the very process of measurement of micro-objects, and it is due to the unavoidable interference of the system of measurement on the measured entity. But apart from such experimental limitations, the theoretical statement of the uncertainty principle indicates that the degree of uncertainty of the electron's position is inversely proportional to the uncertainty of its velocity, or momentum. Thus, precise knowledge of those two properties at one time is even theoretically unfeasible.

In his book <u>Quantum Reality</u> Nick Herbert labels these two attributes as secondary qualities of the electron.[4] This is to say that the electron's position and velocity are not innate characteristics of this wave/particle. They exist in relation to a specific system of measurement. Note the similarity in Democritus' claim that heat and color are only secondary properties of atoms in that they exist only in relation to conscious visual and tactile systems of measurement. But now, in contrast to the atoms of mechanistic materialism, elementary particles are no longer attributed with the intrinsic qualities of position and velocity.

The inconsistency of this interpretation of quantum mechanics lies in the fact that it persists in imputing other primary qualities upon the electron, such as mass, charge and spin. These are its chief innate properties, according to this interpretation, and they are intrinsic to it regardless of the system of measurement. The problem can be stated as follows: How can an electron, whose wave and/or particle status is nebulous, have intrinsic mass,

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[4] <u>Quantum Reality</u>, N. Herbert (Anchor Press/Doubleday, Garden City, N.Y., 1985) p. 46.

charge and spin, when it does not have intrinsic location or velocity?[5]

The mathematical descriptions of the quantum world are reasonably straightforward, and there is widespread agreement as to their accuracy. But what does this tell us of the physical reality of the electron for instance? It is at this point that inconsistencies, vagueness and disparity of opinion arise, and these problems are in no way elucidated by equating such incoherence with religious mysticism. Eastern contemplatives were never subject to the quandary of describing quantum reality with the concepts of European classical physics. Indeed, both modern physics and mysticism question the fundamental nature of reality, but in both areas we must avoid confusing mystification with mysticism.

One of the most common remarks concerning the quantum world is that it is unimaginable, and this suggests to some minds a mystical quality to the science that has made this discovery. Since the time of Democritus, Western thinkers have sought to conceive of the nature of reality as it exists in its own right, apart from our experience of it. The most naive realism assumes that all the qualities that we sense--including color, heat, taste, etc.--are intrinsic

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[5]In light of relativity theory, even the intrinsic mass of the electron becomes problematic, for the mass of a moving body is different when measured from two different frames of reference.

to physical objects. Classical mechanics, following the lead of Democritus, imagines that reality is composed of colorless, tasteless, odorless particles moving silently through space. Quantum mechanics has found that independent physical reality can no longer be conceived as simple discrete particles (due to the wave/particle duality), and their absolute motion is also called into question, for that concept falsely assumes absolute location and velocity.

Those who continue to adopt a realist interpretation of quantum theory continue in the age-old attempt to conceive of physical reality as it exists independently of our systems of measurements. Some go so far as to claim that the ontological status of the microworld is fundamentally different from that of the macroworld. Heisenberg, for example, declares that "atoms and the elementary particles themselves are not as real [as experimental facts about atomic events]; they form a world of potentialities or possibilities rather than one of things or facts.[6] Thus, electrons and their orbits are to be considered as "potentia," rather than real things or events.[7]

This is a common attitude in quantum mechanics: The macroworld of everyday experience retains the ontological status attributed to it in classical mechanics, whereas the

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[6]Cited in Quantum Reality, p. 26.

[7]Physics and Philosophy, W. Heisenberg (Harper & Row, N.Y., 1962) pp. 181 & 186.

microworld demands a different status in accordance with quantum mechanics. Thus, experimental instruments, such as a cathode ray tube, are regarded as classical objects, whereas the entities they are designed to measure are non-classical. Niels Bohr, moreover, recognized the logical necessity of describing the observational means in terms of classical physics.

The strangeness of this logical necessity should be obvious. If an unmeasured subatomic entity exists as a mere potentia, how could two such entities be any more actual or real? Or a hundred or a trillion? If the basic components of physical reality are mere potentia, large quantities of them do not make them any more real; and a macroscopic object such as an apple is presumably composed of nothing more than a large quantity of electrons, protons and so on. What is a cathode ray tube composed of apart from unmeasured subatomic particles?

Perhaps the chief ontological mystery of quantum mechanics is the manner in which subatomic entities, existing as "probability waves" or potentia interact with a system of measurement. Until the measurement occurs and observational results are produced, the Schrödinger equation describes the electron as a probability waves; but when the measurement occurs, that probability wave collapses, and the electron yields actual, not probable, results. The physicist John von Neumann recognized that if the unmeasured electrons that the Schrödinger function describes are mere potentia, the same must be true of the unmeasured elementary particles of which the measuring device is composed. That device must in that case exist as an unimaginably complex system of probability waves and thus as a mere potential. But in this case, how could interaction with such a potential reality collapse the wave function? Following this line of inquiry with his renowned clarity and brilliance of logic, he found nothing in the physical world capable of collapsing the wave function.[8] This led him to the conclusion that this collapse occurs due to consciousness of the event, but this interpretation has its own difficulties. The problem of quantum measurement remains unsolved in contemporary physics.[9] The source of this problem seems to lie once again in the process of reification.

Early twentieth-century physics conceived of the atom as a positively charged nucleus with electrons imbedded in it. This was replaced with the planetary model of electrons orbiting the nucleus, and Bohr modified this picture by allowing the electrons to disappear instantaneously from one orbit and reappear in another. He offered no physical

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[8] It should be emphasized that mathematically speaking the collapse of the wave function is straightforward. It is when one tries to associate the mathematics with physical reality that problems are encountered.

[9] See Quantum Theory and Measurement, ed. by J.A. Wheeler and W.H. Zurek (Princeton Univ. Press, New Jersey, 1983).

explanation as to how this mysterious feat was accomplished. With the advent of the wave/particle duality and the uncertainty principle, physicists were forced to renounce any imagery that supposedly represented the physical reality of the atom as it exists independently of measurement. Heisenberg, Max Born and other prominent physicists made a great point of declaring: Let us not attribute existence to that which cannot be known even in principle.

Such physicists were compelled to restrain their impulse of reification by rejecting all models of what atoms really look like when we are not looking at them or measuring them. But the above principle is difficult to adopt in a thoroughgoing way. In his later writings Heisenberg once again reified such particles, declaring them to exist as "potentia." No imagery is induced by such an ontological claim, but it does set up a paradoxical dualism between the potential status of subatomic entities and the actual, real status of the macroworld, which is composed of nothing other than those potentia.

In taking this step, Heisenberg and like-minded physicists withdraw from their own principle of refusing to posit the existence of that which is in principle unknowable. Experiment does not inform us of the ontological status, or intrinsic nature, of micro-objects as they exist apart from measurement. Given one system of measurement, results are produced that suggest the presence of a wave phenomenon; given another system, the "same" measured object seems to be a particle. In the absence of any system of measurement, we have no evidence of waves, particles or anything else. We may conclude, according to the above principle, that an electron existing as an independent entity is in principle unknowable; and therefore this independent entity does not exist as a potentiality, for it does not exist at all.

CHAPTER SEVENTEEN:

UNCERTAINTY IN THE QUANTUM WORLD

Heisenberg and his school of interpretation of quantum theory likewise violated the above principle of unknowability in their analysis of causality in the quantum world. Over the past few centuries scientists have explored the nature of smaller and smaller entities. The underlying motive has been, as the experimental physicist Rutherford declared, that "if we knew the constitution of atoms we ought to be able to predict everything that is happening in the universe."[1] As physicists probed more deeply into the minute components of matter, they repeatedly encountered anomalous behavior which they gradually accounted for in orderly ways. In the process, more and more fundamental causes were recognized to account for otherwise inexplicable behavior, and in this way the orderly universe was maintained. Where could such a search for causes end? Science might conceivably come up with a first, or primordial cause, which lies at the source of all motion.

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[1]Cited in Rutherford: Simple Genius, D. Wilson (M.I.T. Press, Cambridge, Mass., 1983) p. 391. See also The Second Creation: Makers of the Revolution in Twentieth Century Physics, R.P. Crease and C.C. Mann (MacMillan Pub. Co., N.Y., 1986) p. 32.

But such an Aristotelian idea would generally be regarded as being in the domain of philosophy or theology.

The more likely outcome of this search is that physicists would encounter natural events for which no definite causes could be identified. They are then faced with two options: (1) to admit that at least for the time being, the causes of those events remain hidden from our understanding; or (2) to claim that those events occur at random, without cause. In the second case, no causes are identified for the simple reason that they do not exist. Max Born, who was instrumental in introducing the probabilistic interpretation of quantum theory, declared that deterministic causes of such quantum processes as radioactive decay are in principle unknowable; and as such they do not exist.

Physics has historically been concerned with finding simplicity and order in nature, but when it comes to the quantum level it finds apparently random events for which no direct causes can be identified. This situation could be interpreted as a further level of subatomic order of possibly unfathomable complexity; or one could insist upon fathomable simplicity by interpreting it as subatomic chaos. By renouncing causality one retains simplicity at the cost of order. There is no reason in principle why Western thought could not have arrived at the same conclusion upon inquiring into the nature of the macroworld. Faced with the vast complexity of natural events that we witness, we could have come to the swift conclusion that such things as illness, weather and natural calamities occur at random. But if we had adopted that view early on, it would have precluded the growth of Western science.

A similar theme has been adopted in modern cosmology. Astronomer Edward Harrison claims that the universe began in a chaotic state in which everything is irrational and indeterministic.[2] The original emergence of life and consciousness in the universe is also attributed to "chance" in modern cosmology. When scholastic theology encountered inexplicable elements of reality, it frequently deemed them "mysteries." When science encounters such elements, it now tends to regard them as random, chance events.

The advocates of this view of acausality in the quantum world express only a partial adherence to the principle of unknowability. Without the classical assumption of physical causality, quantum mechanics could never have been formulated; for its rests upon the very classical concepts that it refutes. Without the concept of causality we would not today recognize four basic forces in nature, for they are regarded as being responsible for all natural processes.

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[2] Cosmology: The Science of the Universe, E.R. Harrison (Cambridge Univ. Press, 1981) p. 359.

A strict, consistent adoption of the principle of unknowability must acknowledge that the entire physical world, existing independently of all systems of measurement, is in principle unknowable; and thus it does not exist. But few physicists are willing to go that far. While recognizing that some of the properties of atoms do not exist apart from measurement, they still believe in a real quantum world existing in its own right. However, since strict causality is not knowable in this atomic realm, they conclude that it does not exist. There is an element of inconsistency here: If strict causality is to be discarded on the grounds of unknowability, the entire realm of the unmeasured quantum world should be abandoned on the same grounds.

Physicists who seek to maintain strict causality in quantum mechanics insist upon "hidden variables," mechanisms in the quantum world that are not prone to measurement. These are introduced in order to save the principle of strict causality, and this procedure is often rejected on the grounds that it is _ad hoc_ and artificial. To many scientists the introduction of hidden variables seems to be the only alternative to denying strict causality in quantum mechanics. A third option, however, is to assert that we simply do not know whether atomic processes are subject to strict determinism. We do not even know whether the only possible causes are necessarily of a physical nature. The enormous success of quantum mechanics in accounting for a wide range of phenomena does not rest on the metaphysical denial of strict causality. It would work just as well if physicists acknowledged certain limits to their domain of knowledge; and this might be more responsible than informing society that the fundamental nature of physical reality is irrational and chaotic.

Do at least some of the properties of subatomic entities not have an objective reality independent of the act of observation? In a famous paper entitled "Can Quantum-Mechanical Description of Reality Be Considered Complete?"[3] Einstein attacked this view.[4] As a confirmed realist, he was convinced that any such theory that denies the real, independent properties of such entities must be incomplete. It is a temporary, partial makeshift theory that will eventually be replaced by one that directly represents physical reality in space and time, and that does not assert natural events as analogous to a game of chance.[5]

In the above paper Einstein presents a thought experiment which he felt demonstrated the incompatibility of

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[3]Einstein, Podolsky, Rosen, Phys. Rev. 47, ((1935) 777.

[4]See also Subtle is the Lord...The Science and the Life of Albert Einstein, A. Pais (Oxford Univ. Press, N.Y., 1982) pp. 454-457.

[5]"The Fundaments of Theoretical Physics" from Out of My Later Years, A. Einstein (Philosophical Library, N.Y., 1950) p. 110.

the lack of real properties of subatomic objects and the limitation of the absolute speed of light (believed to be the highest, invariant speed in nature). This came to be known as the EPR paradox and remained a subject of controversy for decades. Almost thirty years after the appearance of that article, John Bell suggested a means to test this paradox empirically.[6] In his work, now known as "Bell's Theorem," he distinguishes between local hidden variable theories and quantum mechanics.[7] The former are theories that posit objectively real parts of a system that can be isolated from one another. Those theories and quantum theory give different predictions for the experiment that Bell conceived of. In 1981, Alain Aspect and his collaborators at the University of Paris's Institute of Theoretical and Applied Optics presented a paper describing their experimental test of the EPR paradox, under conditions in which Bell's type of analysis applied.[8] Experimental results showed that the quantum-theoretical predictions were indeed obeyed.

A common interpretation of this experiment states that it compels us to renounce either thorough-going realism or

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[6]"On the Einstein Podolsky Rosen Paradox," John Bell, Physics 1, (1964) 195.

[7]"Is the moon there when nobody looks? Reality and quantum theory." N. David Mermin, Physics Today, Apr. 1985, p. 38.

[8]A. Aspect, P. Grangier, G. Roger, Phys. Rev. Lett. 47, (1981) 460.

the theory that nothing can travel faster than the speed of light.[9] In the minds of some physicists this clearly refutes realism, thus experiment is seen as deciding a question of ontology. Other physicists, however, interpret the above results in quite another way. For example, N.C. Petroni and J.P. Vigier suggest the possibility of "exchanges of information" occurring faster than the speed of light, and they re-affirm their belief in real particles subject to absolute causality.[10] Such a fundamental diversity of opinion concerning the physical meaning of this experiment supports the age-old truth that any empirical evidence can be subject to multiple, incompatible interpretations.

During the fall of 1985, a conference on quantum reality was held in Urbino, Italy to commemorate the fiftieth anniversary of the EPR paper. Interpretations of the series of experiments on this subject performed by Alain Aspect and his team were hotly debated. However, "only one thing was clear from the discussions that took place: It is difficult to find agreement even on minor issues."[11] Duch

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[9] "Experiment and the nature of quantum reality," T. Mike Corwin and Dale Wachowiak, The Physics Teacher, Oct. 1984, p. 425.

[10] "Dirac's Ether in Relativistic Quantum Mechanics" in Quantum, Space and Time--The Quest Continues, ed. A.O. Barut, A. van der Merwe, Jean-Pierre Vigier (Cambridge Univ. Press, N.Y., 1984) pp. 522, 526.

[11] "Microphysical Reality," W. Duch and D. Aerts, Physics Today, June, 1986, p. 14.

and Aerts conducted a poll of fifty-six physicists and other scholars at the conference, who gave answers that seemed representative of physicists working on the foundations of quantum mechanics. Among them, 30% believed that recent experiments had falsified Einstein locality, while 57% did not; 21% asserted, while 52% refuted that there is an influence faster than light; and 86% of them considered themselves to be realists.

Experiment, even as carefully devised as those of Aspect, once again fails to compel physicists to adopt anything like a unanimous view of physical reality. As in the case of the EPR paradox, we should not expect the problem of quantum measurement to be solved by some as yet undevised experimental test. Empirical evidence will continue to be interpreted in diverse ways in accordance with such non-scientific influences as metaphysical predilection.

CHAPTER EIGHTEEN:

PHYSICAL REALISM IN REVIEW

While noting that physicists who are concerned with the foundations of quantum mechanics have difficulty in agreeing even on minor issues, we must also recognize that the majority of physicists express little or no interest in such questions. The training that most physicists receive neither encourages such a concern, nor does it educate them in addressing their minds to subjects that may border on the philosophical. One rough-and-ready retort to problems of interpreting the formalisms of quantum mechanics is simply that "they work"; and this presumably suffices to ensure the validity of this branch of physics.

However, the fact that those formalisms on their own make no statement about physical reality, apart from quantitative measurements, should be apparent. If we are to develop a view of physical reality based upon quantum theory, those formalisms must be interpreted. In his book Quantum Reality Nick Herbert presents no less than eight major contemporary interpretations of quantum mechanics. Most of them are conceptually mutually incompatible, and all equally account for appearances. Thus, if quantum mechanics is "true" because it works so well, we must ask: "Which interpretation is true, for they all work equally well?"

Since the time of Greek antiquity, Western thinkers sought to understand the nature of physical reality in its own right, apart from human experience and concepts. Not only have we adopted this goal from the Greeks, we have also assimilated many of their metaphysical assumptions in the pursuit of that goal. Beliefs in autonomous atoms moving through the void and in the presence of mathematics imminent in physical reality, and the insistence on beauty and simplicity are all legacies from our Greek heritage. Newton's assumption that mind is separate from nature and that the physical world can be understood while ignoring the existence of human consciousness also traces back to such Greek thinkers as Democritus. So, too, does Leibniz's principle of conservation find its origin in pre-scientific thought.

The point is that Western science has not followed a course of inquiry into physical reality demanded by Nature herself, nor have we followed the one reasonable approach. Rather, we have followed a course that is based on and continues to be influenced by the unique Greek and Hebrew roots of our culture. In pursuing this mode of inquiry, we have developed a view of physical reality that differs starkly with those of other civilizations such as classical China and India. A common tendency among scientists and their devotees is to judge alien views of reality with the sense that insofar as they differ from modern science, they are false. This dogmatic conviction implicitly assumes that the pre-scientific, metaphysical assumptions upon which Western science is based are the only true ones. We are free to make such a claim, but it is misleading to suggest that it is a scientific conclusion.

A scrutiny of modern descriptions of reality by physicists shows obvious influences of logical positivism, materialism, phenomenology, existentialism, pragmatism and other contemporary currents of philosophical thought. Only the most naive appraisal of the history of ideas could lead to the conclusion that the "hard facts of physics" lie at the source of these philosophies.

With the development of the science of mechanics during the eighteenth century, physicists found less and less need to resort to the hypothesis of a God to arbitrate in the operation of the physical universe. During the following century, with the adoption of the principle of energy conservation and the materialistic model of the universe as a mechanism, God seemed yet more superfluous. Indeed, as scientific advances appeared gradually to undermine the credibility of religious doctrine altogether, an increasing number of scientists and their devotees discarded religion as a whole. This tendency has continued into the present century.

During the opening decades of this century, one occasionally hears a physicist use a theological argument in support of a physical theory. Einstein, for example, challenged certain probabilistic assumptions in quantum theory on the grounds that "God does not play dice." Most contemporary physicists, however, would side more with Bohr's response that we should not tell God what He can do. The prevailing attitude is that scientific theory must be kept strictly free of religious prejudices. Thus, even if a physicist believes in God, he must not let that bias taint his scientific thinking.

Let us, for the moment, define religious doctrine as a system of belief concerning such issues as the nature of the Ultimate Being, the essential meaning of human life, the origin of the universe, the destiny of the individual following death, and the means to salvation. Viewed in such terms, it becomes immediately apparent that contemporary science is thoroughly suffused with religious doctrine. That doctrine may vary anywhere from agnosticism to unequivocal atheism. In this sense, twentieth-century physics is as profoundly influenced by metaphysics and religion as it was during the time of Newton. This fact may be overlooked by today's practicing physicists, for their training does not encourage them to reflect on the philosophical and religious foundations of their discipline. Scientists cannot really choose whether they will be free of such influences, for scientific thinking does not occur independently from the rest of our thinking. Those who are affected by science can only choose whether they will consciously, intelligently reflect upon its historical development and metaphysical foundations.

Since the time of Newton, there has been virtually universal agreement that physical science has made tremendous progress. Over the years there has been widespread agreement among physicists as to the progress in mathematical and experimental techniques. There has also been a general consensus concerning the heuristic value of popular physical models. The picture of electrons circling about an atomic nucleus, like planets about a sun, for example, is still very much in use, even though it is no longer believed to correspond with any physical reality. What is an electron really? Is it a wave or a particle? Does it have definite location and velocity? Is it an independent physical reality or purely an abstract concept or a set of physical relations? How many electrons could perform a chaotic random-walk on the head of a pin? Physicists' responses to these ontological questions appear to vary as much as the speculations of medieval theologians concerning the ontological status of angels.

Science has long prided itself on it unique progress, in contrast to the idle speculations of philosophy and the unverifiable tenets of religion. Kant expressed this attitude when he reflected that metaphysics is always "keeping the human mind in suspense with hopes that never fade, and yet are never fulfilled...while every other science is continually advancing."[1] Let us recall for a moment the diversity of conceptually incompatible views that account for the Casimir effect. This situation of multiple theories equally accounting for the same phenomena is actually quite common in physics, though it is not commonly brought to the attention of students or the public at large. The realists' creed is that such diversity will disappear when a broader range of more precise experiments has been conducted. By a process of steadily more exacting elimination, false theories will be found inadequate, and the culmination of this evolution will be a single grand unified theory that will consistently, accurately account for all phenomena in the one correct way.

According to this view, as scientific research continues there should be ever increasing agreement on first the major aspects and then the subtle points of physical theory. The present diversity of views on the Casimir effect, the implications of the Aspect experiment, and more generally the nature of quantum reality should encourage us to question the above realist assumption. There has always been fundamental diversity of interpretations of mathematical theories and experimental evidence, and there is no evidence that this tendency is on the decline. If

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[1] Prolegomena to Any Future Metaphysics, I. Kant (Mahaffy) p. 2. Cited in A History of Philosophy, Vol I, Frederick Copleston, S.J. (Search Press, London, 1946) p. 3.

this is the case, the prospects seem remote for the scientific community ever to agree universally on a single grand unified theory. To paraphrase Kant, the realists keep the human mind in suspense with hopes of such a unified theory which never fade, and yet are never fulfilled.

A.N. Whitehead made an observation similar to Kant's when he noted: "European thought is represented as littered with metaphysical systems, abandoned and unreconciled."[2] However, he goes on to add that if that means ill-success, the same can be said of science. Over the entire course of its history, physics has moved from one diversity of views to another; and always it has developed hand-in-hand with prevailing metaphysical and religious beliefs. It has indeed progressed, but not in the manner assumed by the prevailing view of realism.

In the historical and philosophical inquiry into the foundations of physics presented here, we have encountered diversity, inconsistency and at times naivety in physicists' views of their discipline. Does physics indeed shed light on an independent, intrinsic physical reality? Are the foundations of physics secure? Einstein, who had a lifelong commitment to a realist interpretation of physics, plainly acknowledged:

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[2] Process and Reality, A.N. Whitehead (The Free Press, N.Y., 1978) p. 14.

For the time being, we have to admit that we do not possess any general theoretical basis for physics, which can be regarded as its logical foundation.[3]

[3] "The Fundaments of Theoretical Physics" from Out of My Later Years, p. 110.

CHAPTER NINETEEN:

MATHEMATICAL REALISM

Modern physics has come to describe nature in ways that cannot be understood with visualizable models. A most common statement in quantum mechanics is that the atomic realm cannot be imagined. Matter is neither simply a wave nor a particle, and the uncertainty principle further discourages any attempt to visualize the quantum world. Energy, as an objective, conserved entity, has never lent itself to our powers of visualization; nor can we clearly imagine a field such as those proposed in quantum electrodynamics. Spacetime, as conceived in general relativity, also defies the imagination. According to modern cosmology, the spacetime of the universe is itself expanding, accounting for the increasing distances between galaxies. Into what is it expanding? Cosmology replies that there is no higher dimension into which it expands; and this, too, does not lend itself to the imagination. In short, modern physics, despite its numerous heuristic models, discourages us from trying to imagine the basic constituents of physical reality. It simply cannot be done.

This statement is closely related to another common assumption among physicists, namely, as Einstein claimed, that "nature is the realization of the simplest conceivable mathematical ideas."[1] It is interesting to note, however, that he also acknowledged that "as far as the propositions of mathematics refer to reality, they are not certain; and as far as they are certain, they do not refer to reality."[2] While there is fundamental dissention among physicists as to interpretations of quantum mechanics, there is widespread agreement concerning its mathematical formalisms.

To a mathematical realist this may suggest that a true physical theory is purely mathematical in nature, and any interpretations using physical concepts are beside the point. Nature in its own right cannot be grasped with ideas expressed in the words and grammar of English, German or any other human language. Rather it can be grasped only with pure mathematical thought.[3] Moreover, "one reason why mathematics enjoys special esteem, above all other sciences, is that its propositions are absolutely certain and indisputable..."[4] Thus, it should come as no surprise that modern concepts of matter, energy, fields and spacetime, which are products of mathematical thought, are not amenable to the non-mathematical imagination.

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[1] "On the Method of Theoretical Physics" from Ideas and Opinions, A. Einstein (Crown Pub., Inc., N.Y., 1954) p. 274.

[2] "Geometry and Experience," ibid., p. 233.

[3] "On the Method of Theoretical Physics" from Ideas and Opinions, A. Einstein, p. 274.

[4] "Geometry and Experience," ibid., p. 232.

This metaphysical assumption, like so many others underlying modern physics, traces back to Greek antiquity. The early atomists, like the Pythagoreans, believed that the underlying reality of the physical world is expressible in terms of mathematics.[5] For Plato, mathematics is an intrinsic element of the absolute, unchanging, transcendent realm of Ideas, and the less real physical world can be understood only through the mathematics of the ideal world. Both he and Aristotle agreed, though for different reasons, that mathematical axioms need not be proved, for their truth is unquestionably self-evident. The effort to understand nature through mathematics continued during the Middle Ages, and the chief impetus for this movement was attributed to Euclid's Elements.

From Pythagoras, Kepler adopted the approach of treating observed physical phenomena as approximations of mathematically "clean" conceptions; and this has developed into a defining property of physical inquiry. During the era when modern science emerged and grew, mathematicians from the sixteenth to the eighteenth centuries commonly regarded their work as a religious quest. Descartes, for example, believed that the truths of mathematics are innate to the human mind, having been placed there by God. Galileo went further in stressing the importance of a mathematical

[5]The following historical discussion is based largely on Morris Kline's provocative book Mathematics: The Loss of Certainty (Oxford Univ. Press, N.Y., 1980).

description of nature, as opposed to Descartes' emphasis on physical explanation. Both men felt that all of science should be patterned after mathematics, moving from self-evident axioms to logical deductions.

As we have noted previously, Newton was drawn both to the austerity of a mathematical description of physical processes as well as to the more imaginative goal of physical explanation. He believed that his mathematical principles of mechanics give a true account of phenomena on the grounds that God created the universe in accordance with mathematical principles. Thus, his theology preceded and justified his science. Newton even claims that he wrote his Principles with "an eye on such principles as might work with considering men for the belief in a Deity."[6]

During the eighteenth century, religious inspiration for work in mathematics began to decline, and during the following century even belief in God among mathematicians decreased. Such a process of secularization inevitably lead to the question: If God did not create nature in accordance with mathematical laws, why should we believe that they are present in physical reality?

In 1753, Diderot was among the first to suggest that mathematics is an artificial convention with no foundation in reality. A major impetus for such questioning was the

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[6]Letter to Rev. Richard Bentley of Dec. 10, 1692. Cited in Mathematics: The Loss of Certainty, p. 59.

emergence of geometries using axioms other than those of Euclid. Gauss developed his system of non-Euclidean geometry in 1813, and he was the first to suggest the physical applicability of such a system and to question the truth of Euclidean geometry. In 1830, Bolyai and Lobachevsky went a step further in suggesting independently, that none of Euclid's postulates are either true or false. Rather they are simply the rules of the game. In 1843, the mathematician William Hamilton devised a new system of physically useful algebra in which the commutative law for multiplication is denied, i.e."a x b" does not equal "b x a." His work was followed by other algebras with yet other rules of the game.

Only in the nineteenth century did modern scientists seriously suspect that mathematical axioms may be derived from experience and not from innate reason. Helmholtz claimed that the very concept of number stems from experience and that only experience can tell us where the laws of arithmetic apply. For example, if we add one volume of water at forty degrees temperature to an equal volume at fifty degrees, only experience informs us that the temperature of the combined volumes is not ninety degrees.

During this century it began to appear that mathematical axioms are derived, directly or indirectly, from experience and that the physical applicability of arithmetic and other branches of mathematics is determined only by experience. But if this is the case, there is little justification for believing that mathematics contains truth in the sense of laws of physical reality as it exists independent of experience. This possibility was metaphysically so repugnant to nineteenth-century mathematicians, however, that many rejected it out of hand.

Up to the beginning of the sixteenth century, the concepts of mathematics tended to be immediate idealizations of or abstractions from experience. But in the following centuries such mentally-originated notions as complex numbers, derivatives and integrals were introduced that could not be visualized or abstracted from everyday experience. Such mathematical concepts have been devised not for their conceptual simplicity, but for their amenability to clever manipulations and to striking, brilliant arguments.[7] As physical theories came to be formulated in terms of increasingly abstract mathematics, it was inevitable that the physical reality they describe be decreasingly amenable to visualization. The unimaginability of the quantum world, for example, was a foregone conclusion, given the abstract formalisms in which quantum theory is couched.

In the seventeenth and eighteenth centuries, vagueness and logical gaps in mathematics were usually overlooked due

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[7] "The Unreasonable Effectiveness of Mathematics in the Natural Sciences," Eugene P. Wigner, Communications of Pure and Applied Mathematics, 13, 1960, p. 7.

to the success of physical applications of mathematics and due to the belief that God created a world that operates on mathematical principles. However, during the eighteenth and nineteenth centuries, mathematicians became increasingly concerned with proving the rigorous internal consistency of the entire body of mathematics. Progress toward this goal focussed first on calculus, then algebra, complex numbers, irrational numbers, fractions and finally whole numbers. By 1890, this process of rigorization was widely considered to be complete: The logical foundation for all of mathematics was secure. We note, however, that what seemed established was the internal consistency of mathematics, not its truth.

One mathematician who was not so confident about this complete rigorization was David Hilbert. Just as physics in the closing years of the nineteenth century seemed complete, barring a few unsolved anomalies, so did mathematics have a few residual problems in need of solution. Hilbert identified twenty-three such problems, and one of them was a proof that arithmetic is consistent.

The mere fact that physics at times seemed to confirm the truth of mathematical principles was recognized, by 1900, as being no proof of the consistency of mathematics. As the century progressed, new contradictions in mathematics were produced and old ones revealed by such innovations as the theory of infinite sets. Thus, mathematicians of the early part of this century were faced with the severe

problems of resolving present contradictions in their science and of proving its thorough consistency to ensure that no new contradictions would arise.
The assurance in the logical foundations of mathematics at the end of the nineteenth century turned out to be as unfounded as the similar attitude towards physics at that time.

In what sense do mathematical concepts exist? This was the basic, underlying issue in the attempt to establish mathematics on a firm foundation. By 1930, four distinct, conflicting schools of thought had arisen, and the major problem which motivated them--the consistency of mathematics--was not settled at all. Equally competent experts disagreed on the simplest aspects of any reasoning that makes the slightest claim to universality or cogency.

In 1931, the mathematician Kurt Gödel presented a proof that undermined the entire pursuit of consistency for the whole of mathematics.[8] In his "incompleteness theorem" he demonstrated that if any formal theory adequate to embrace the theory of whole numbers is consistent, it is incomplete. This indicates that there exist meaningful statements that belong to, but cannot be proved within, those systems. Those statements can be shown to be true or false by non-formal arguments which rely on axioms outside the system.

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[8] cf. Gödel's Proof, Ernest Nagel and James. R. Newman (New York Univ. Press, 1964).

Until this time, it was widely assumed that a complete set of axioms could be assembled for any given branch of mathematics. Gödel showed, however, that the set proposed in the past for arithmetic was incomplete and that it could not be made complete simply by adding a finite number of axioms to the original list. Thus, any system in which arithmetic can be developed is essentially incomplete. The complete axiomatization of all of mathematics was now seen to be hopeless.

Subsequent investigations into the foundations of mathematics after 1931 further frustrated any attempt to determine the nature and validity of mathematical statements. The Löwenhein-Skolem theory, for example, demonstrated that a set of theorems permits many more essentially different interpretations than the one intended. Once again the problem of multiple, incompatible interpretations, which has plagued the foundations of physics, emerges in mathematics as well. Faced with the implacable contention among diverse schools of thought, mathematicians have been forced to accept that there is no such thing as an absolute, or universally accepted, proof.

Mathematical axioms, which were traditionally regarded as self-evident truths, are now recognized as conventions. If a set of axioms for a given system were to be complete, all logical truths based on those axioms would be tautologous. But such a complete set is not possible even for arithmetic. In any arithmetic system further truths may be established not tautologically, or on the basis of its axioms, but by some form of metamathematical reasoning.

If a system as comparatively simple as arithmetic is not self-contained, we may wonder how a grand unified theory for all of physics could possible have that quality. What is the search for a grand unified theory if not for a complete, consistent theory accounting for all natural phenomena? May it not be that metaphysical reasoning may be necessary to account for certain physical truths, just as metamathematical reasoning establishes certain mathematical truths? If the axioms of arithmetic must remain essentially incomplete, is it not reasonable to expect the same for physical principles?

Just as most contemporary physicists have little interest in or knowledge of the problems lying at the foundations of their science, so is this true of many mathematicians. In both disciplines there are some who are aware of the problems but discount them as being of a philosophical, rather than of a scientific nature. As in physics, the fundamental unresolved problems and uncertainties are not generally taught to students; and in this way the myth of the absolute truth of mathematics and of the mathematical nature of independent physical reality is nurtured.

Bertrand Russell, who devoted much of his life to establishing the consistency of mathematics, eventually was compelled to abandon the view that the axioms of logic are self-evident truths. Moreover, having established that mathematics is derived from logic, he concluded that it, too, is not based on infallible truth. In a famous epigram he remarked that "pure mathematics is the subject in which we do not know what we are talking about, or whether what we are saying is true."[9] Hermann Wehl, another of the foremost mathematicians of this century, made a similar comment in 1940:

> In spite, or because, of our disposed critical insight, we are today less sure than at any previous time of the ultimate foundations on which mathematics rests.[10]

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[9] Cited in Gödel's Proof, E. Nagel and J.R. Newman, p. 13.

[10] Cited in Mathematics: The Loss of Certainty, p. 319.

CHAPTER TWENTY:

INSTRUMENTALISM

Especially during the twentieth century, trends in physics and in the attitudes of physicists have made it increasingly difficult to defend a view of realism in the foundations of science. Ernest Rutherford, who presented himself as the epitome of an experimenter and who performed pioneering research in atomic physics, had a virtual contempt for theorizing in physics. The facts of nature, he thought, are to be discovered through experiment, not through theorizing. And yet when he performed an experiment, he liked to have a clear pictorial image of what was going on. Such an image is nothing more than a theoretical model, and without it or some other theory, the experiment conveys no information whatever. Rutherford also adhered to metaphysical principles in his work, as illustrated by his comment that "if we knew the constitution of atoms we ought to be able to predict everything that is happening in the universe."[1] Thus, like so many of the views of his nineteenth-century predecessors in science,

[1]Cited in Rutherford: Simple Genius, D. Wilson (M.I.T. Press, Cambridge, Mass., 1983) p. 391. Punctuation and capitalization are slightly altered for readability by R.P. Crease and C.C. Mann in their work The Second Creation (MacMillan Pub. Co., N.Y., 1986) p. 32.

Rutherford's naive realism in physics and his unconscious metaphysics became vulnerable under the onslaught of later developments in quantum mechanics.

While the experimentalist Rutherford was impatient with physical theorizing, the theoretician Paul Dirac displayed a similar disinterest in philosophizing or investigating the foundations of physics. As a youth he enjoyed playing with equations and looking for beautiful mathematical relations, regardless of any possible physical meaning that they might have. His formal education was in mathematics and engineering, and for most of his life he found philosophy and the arts nearly incomprehensible.[2] This limitation, however, did not prevent him from becoming one of the chief architects of quantum mechanics, the creator of quantum electrodynamics and one of the principle founders of quantum field theory. Dirac certainly believed that quantum theory explained processes in the real physical world, and he was concerned that mathematical techniques be physically justifiable. But his comparative lack of training and reflection in philosophy placed him in a difficult position to defend his realist interpretation of modern physics.

Among the generations of physicists following that of the founders of quantum mechanics, interest in the foundations of modern physics has, until quite recently, waned yet further. Contemporary theoreticians tend to be

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[2] The Second Creation, p. 76.

less concerned than Dirac with physically justifying their calculations, such as renormalization techniques in quantum electrodynamics. The prevailing view seems to be: If the mathematical theory makes valid predictions, it is to be adopted regardless of any physical justification for it. The ends justify the means. Even in the early years, it was not uncommon for researchers to claim that they wanted to restrict their theories only to quantities they could observe. A movement began to desist from making statements about physical reality, and this has led to the present observation that physicists never understand quantum mechanics, they just learn to use it.

David Bohm, for example, comments that in quantum mechanics there is no physical notion of what movement means. Physicists simply use the mathematics of this theory to calculate results, saying that they have no meaning whatsoever other than that. "They do use the idea of fields and particles and so on but when you press them they must agree that they have no image whatsoever what these things are, and they have no content other than the results of what they can calculate with their equations."[3]

We recall that Copernicus sought to "save the appearances" by means of hypotheses that conform to certain physical principles (some of them Aristotelian), and on the

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[3]Interview with D. Bohm, The Holographic Paradigm and other Paradoxes: Exploring the Leading Edge of Science, ed. Ken Wilber (Shambala Press, 1982) p. 52.

grounds of such physical justification he proposed that his theory was true of nature. In contrast, many medieval astronomers demanded of their theories only that they be as simple as possible and that they account for appearances as precisely as possible. By not insisting that their theories be physically justifiable, they relinquished any claim to their being physically true.

Similarly, if particle physicists no longer demand that facets of their mathematical formalisms be physically justified--if only simplicity and accuracy of results are required--they, too, must not pretend to be describing and explaining the fundamental components of physical reality. Their concepts must be regarded as instruments for making correct predictions, not as representations of physical entities. Fields and elementary particles must be regarded as no more real than the equants and epicycles of medieval astronomy.

Although the physical reality of the entities described in such fields as quantum electrodynamics is extremely hard to defend, few physicists seem inclined to make this known publicly. We have noted internal inconsistencies in quantum theory due to its awkward relationship with the concepts of classical physics. There appears to be another level of inconsistency in terms of the ontological status of the quantum world. When modern physics is taught to students or explained to the general public, it is usually presented as a portrayal of physical reality itself. Internal inconsistencies are overlooked and dissention concerning the interpretation of mathematical theory is ignored. But when physicists are hard-pressed by someone who is aware of the problems in the physical interpretation or meaning of various theories, they often retreat to the safety of an instrumentalist position: The mathematical formalisms are not really regarded as true, they are simply effective instruments for making a wide range of accurate predictions.

If physics is in fact capable only of accounting for appearances in a manner similar to that of Ptolemaic astronomy, a realist view of physics is untenable. The chief alternative view is known as instrumentalism. From this perspective a physical theory is valuable for its organizing role in making predictions, but it is not posited as being either true or false. A theory, like any other instrument, may be more or less useful, but the question of its validity simply does not arise. It is regarded as a "leading principle"[4] in accordance with which conclusions about observable facts may be drawn; but it does not explain why those facts are observed. Accordingly, theoretical entities, such as fields and elementary particles, which are

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[4] The Structure of Science, E. Nagel (Hacket Pub. Co., Indianapolis, 1979) p. 130.

never directly observed, are merely conceptual constructs without any presumed referents in reality.

According to instrumentalism, one theory may still be superior to another if (1) it serves as an effective leading principle for a more inclusive range of inquiries than does another and (2) it supplies a method of analysis and representation that makes possible more precise and detailed inferences than another. In short, a good theory is one that is broadly encompassing, simple and precise in terms of its predictions. Its approximation to reality is not an issue. Thus, Newton's first law of motion is superior to Aristotle's account of the natural motion of bodies because Newton's physics require fewer ad hoc explanations.

A similar instrumentalist view may be adopted towards mathematics. One may argue that the rules of mathematics are as arbitrary as the grammatical rules of any other human language, and they may vary from one culture to another. Thus its "truths" are simply conventions, and mathematical theories are nothing more than instruments. Many twentieth-century researchers in the foundations of mathematics have such a view: Mathematics is justified only by the degree of its success at practical physical application, i.e. in giving correct results.

Instrumentalism is widely regarded as a pragmatic and logically invulnerable view of science--a safe fall-back when one's realism temporarily comes under serious attack. In fact, it is neither truly pragmatic nor logically sound. Its proponents supply no uniform account of the various "scientific objects" (e.g. electrons and light waves) that are ostensibly postulated by theories concerning the microworld. If such terms as "field" and "particle" function only as conceptual links in rules of representation and inference, it is unclear in what sense they can be regarded as physically existing things. A truly consistent instrumentalist must renounce any claim that such theoretical entities have any existence outside the human mind.

An instrumentalist regards only observable phenomena as real. All theoretical entities that are not susceptible to direct observation are no more than conceptual constructs bearing no existence in physical reality. Thus, particle physics yields no knowledge of the hidden nature of the microworld; it only accounts for directly observable effects in the laboratory. Although this view is touted as being pragmatic, what experimental physicist would devote a lifetime to research if he or she felt that experiments yielded no knowledge of physical reality apart from the measurements themselves? If one were convinced that the atomic nucleus is simply a useful concept for organizing data, what incentive would there be for performing extremely sophisticated, careful experiments to explore its internal structure? Moreover, if elementary particles have no existence in physical reality, what is to persuade the public to spend billions of dollars on particle accelerators? They would provide us with more exorbitantly costly data which might require the creation of a new conceptual construct. A view of physics that provides little or no incentive for pure experimental research can hardly be called pragmatic.[5]

Is instrumentalism logically unassailable? Such a view is based on the assumption that there is a clear demarkation between theoretical entities and observed phenomena. The latter are presumably accessible to unmediated observation. The former are based on the latter, but different theoretical entities may be posited on the basis of the same phenomena, due to varying theoretical principles. Thus, theoretical entities are mere conceptual tools, while observed phenomena are real. This view, however, ignores the fact that, as Einstein pointed out, it is the theory that determines what can be observed. This insight, while profound, is not a recent one. As Kant point out, "experience is itself a species of knowledge which involves

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[5]Clearly there are physicists, mathematicians and engineers who are willing to pursue research even if it yields no understanding of the nature of physical reality. The governments of many nations are also willing to finance such research. The motive in such cases tends to be entirely pragmatic: The ideal of the pursuit of truth is replaced by the desire for power.

understanding."[6] The facts that we observe have already been subject to interpretation as soon as they have been ascertained.

If we are to deny the physical reality of theoretical entities that are not amenable to unmediated, direct observation, we cannot confine such a category to the microworld of particle physics. Many of the physical concepts in astronomy, too, concern objects that are hidden from direct observation. Black holes, for instance, must all be relegated to the status of mere concepts bearing no noumenal physical referents. Thus, science must renounce any claim of knowing either the microworld of quantum mechanics or the distant, unobservable macroworld of astronomy and cosmology; for all of these sciences are concerned with theoretical entities that are hidden from direct observation.

Logical consistency does not allow instrumentalism to judge merely the sciences of quantum mechanics and cosmology, concerning entities that are very small or distant in time and space. Electron microscopes, for example, yield observational facts, but these are not unmediated glimpses of the atomic realm. Rather, the observed data ostensibly result from interactions of electrons and atoms as well as other elements of the

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[6] The Critique of Pure Reason, I. Kant, trans. N. Kemp Smith (2nd ed., London, 1933) p. 22.

experimental device. The photographs obtained using such a microscope, therefore, do not show atomic or molecular entities themselves. Rather, such observed results are mediated by the types of measuring instrument that is being used. This is equally true of observations made through an optical microscope. One sees not the investigated subject itself, but the effects produced by its bombardment by photons and the influence of the microscope on the reflected light. Microscopes yield visual results, but the theoretical terms of chemistry ostensibly concern objects that exist independently of such visual observations. Thus, from a thorough-going instrumentalist viewpoint, the chemical bonds and valences discussed in chemistry must also be relegated to the status of mere concepts with no noumenal referents in the physical world.

If the visual data obtained through an optical microscope does not reveal the intrinsic nature of the examined object, but only an interaction between it and photons and the measuring instrument, the same must be true in the case of optical telescopes. Thus, the purportedly physical entities that are posited on the basis of such data in astronomy must also be relegated to the status of mere concepts, and not physical reality. The more closely we examine the process of identifying physical objects, the more we encounter what are in fact theoretical entities; and consistent instrumentalism is compelled to deny that they exist in nature.

Now the visual data that are obtained with the use of microscopes and telescopes are not of a nature essentially different from those observed through normal eyeglasses or with the naked eye. In all such cases we detect patterns of light and color, and these subjective sensory impressions are not intrinsic characteristics of physical objects. In fact, as Democritus recognized, the color patterns observed by humans are relational attributes that have no existence apart from the human act of observation. This is equally true of all our other sensory impressions of sound, smell, taste and touch. All such subjective sensations occur as interactions between the sensed objects and our "cognitive instruments of detection." Photographs of traces of subatomic particles in a cloud chamber are also interactions between the measured objects and the system of measurement. Thus, if for that reason subatomic particles are regarded purely as theoretical constructs, the same must be said of all the macro-objects that we think we observe in the physical world. If the former lack physical reality, so must the latter. In this case, no "observational entities" remain in the physical world. All physical objects that presumably exist independently of our senses are reduced to theoretical entities, and their physical status is thereby renounced.

At this point, the only observational entities are of a cognitive nature: We directly detect the subjective sensations derived from our sense faculties; but the presumed real physical world hidden behind such appearances remains as unknowable as the subatomic realm. All experiential data obtained by means of scientific instruments or our senses must be subject to interpretation before we can "make any sense of them." And in all cases, the bare data can be interpreted in diverse ways. The specific interpretations that we choose are not demanded by the data but by our metaphysical assumptions and other influences.

Instrumentalism, which is widely regarded as logically unassailable, is based upon the assumption of a fundamental distinction between theoretical and observational entities. Objects of the everyday physical world are considered to be observational entities, and their real status is thereby preserved. Upon analysis, however, it appears that this ontological distinction between micro-objects and macro-objects is a fiction. If the only remaining observational entities are our sensory impressions, instrumentalism turns out to be a thinly veiled form of solipsism: We know nothing of the physical world existing independently of our senses. All that any individual knows of the world are his or her cognitive sensations.

Galileo, the founder of modern science, designated the physical world independent of our senses as the domain of inquiry of natural science. Quantum mechanics has thoroughly undermined his distinction between primary and secondary attributes of the basic constituents of physical reality. Location, size, shape and absolute velocity--all regarded as primary physical properties--vanish in the context of individual particles. This leaves us, at least for the quantum world, with relational, secondary properties only. Our senses likewise offer us only relational properties of theoretical entities. Thus, instrumentalism not only denies implicitly that science contains any knowledge of the physical world, it also implies that nature is hidden from our senses.[7]

Although this fall-back view of physics is thought to be

pragmatic and logically invulnerable, it turns out to remove any real incentive for pure, empirical scientific research and to deny the possibility of any knowledge of the physical world. This qualifies it as pragmatically useless and logically barren.

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[7]We note, thus, that both realism and instrumentalism adopt a transcentalist view of reality: The real physical world is hidden behind the appearances of the senses. Transcendental realism assumes that it can be known by means of scientific inquiry; and transcendental instrumentalism asserts that it cannot.

CHAPTER TWENTY-ONE:

SUMMING UP

When modern physics is taught to students and explained to the public, it is usually presented from a realist perspective: Quantum mechanics and so on represent the world as it really is. To science students this view may seem to be confirmed on the basis of the tremendous success of physics in yielding correct results and predictions. The general public may be persuaded of the truth of physics due to the technological wizardry that it makes possible. However, a critical appraisal of physical theory indicates that neither of those reasons are sufficient for positing that science represents the world as it exists independent of the human mind.

As medieval astronomy and modern quantum field theory demonstrate, it is possible to "account for phenomena," to make accurate predictions, without really understanding the physical processes that occur apart from one's measurements. Nor does the ability to manipulate physical phenomena necessarily indicate knowledge of a physical world behind those phenomena. Technology is concerned with observable results, not the fundamental nature of reality.

The realist view sets a very precarious goal for science: to understand the world as it exists independently of human experience and concepts. On what grounds shall we believe that a world that is presumably unrelated to human thought can be grasped by it? The belief that it can be grasped by mathematics but not by words is untenable, for mathematics is as much a human language as any natural language. As such, its axioms and rules are as much human conventions as English grammar and Aristotelian logic.

Instrumentalism, the major alternative, fall-back interpretation of physical theory, turns out to be pragmatically and logically inadequate. Although other non-realist perspectives, such as operationalism, descriptivism and the received view of science have been proposed, they essentially suffer from the same shortcomings as those of instrumentalism. In short, once the mists have cleared from the presumed logical foundations of physics and mathematics, we find that those foundations in reality do not exist at all. Physics, the bedrock of natural science, appears to hover in an ontological vacuum.

At the birth of modern science in the sixteenth century, natural philosophers became increasingly skeptical of many beliefs that were apparently backed merely by authority and tradition. The scientific emphasis was on empirical confirmation rather than purely logical persuasion. Thus, the suppositions of Aristotelian science and gradually Biblical statements came under scrutiny; and in light of this "show me!" attitude, many of them were found wanting. Natural science thus came to be regarded as the chief instrument for routing out and vanquishing superstitions. As this reputation grew, increasing numbers of devotees of science took the further step of discarding as superstition <u>anything</u> that was not based on scientific inquiry.

Closely related to the development of modern science was the widespread adoption of "transcendental realism" as the metaphysical arena for scientific research. Largely due to the influence of Descartes, the real world of nature was regarded as existing "behind the appearance of the senses." According to Descartes, physical reality is utterly unlike our direct, subjective experiences of the world. It is composed of inert matter in motion, devoid of mind or any of the secondary qualities of color, smell, sound, etc. Although hidden from the senses, the mechanism of nature can be known by <u>reason</u>, specifically mathematical reasoning.

Thus, the scientific revolution, while rebelling against the rationalism of medieval scholasticism, substituted its own form of rationalism: The shift was simply from the qualitative to the quantitative. Galileo, however, viewed mathematics in quite a different light. Drawing a sharp demarkation between mathematical demonstration and logic, he asserted that only the former unlocks the secrets of nature. "We do not learn to demonstrate from the manuals of logic," he writes, "but from the books which are full of demonstrations, which are the mathematical and not the logical."[1] As noted previously[2], twentieth-century investigations into the foundations of mathematics have discredited this view.

Galileo and Descartes were both certainly interested in careful observation and experiment, but these were seen as means for explaining the reality hidden behind the world that is accessible to experience. If a mathematical theory could be devised that accounted for appearances in a manner filling the requirements of simplicity and beauty, it was deemed true of nature. For they already assumed that nature is intelligible and operates according to simple and beautiful mathematical laws. Neither of these pillars of modern science wanted to confront the possibility that multiple, conceptually incompatible mathematical theories might equally account for the same observations and experiments. Nor did they seriously entertain the idea that simplicity and beauty might be in the mind of the theoretician.

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[1]Opere, I, 42. Cited in E.A. Burtt's The Metaphysical Foundations of Modern Physical Science (Harcourt, Brace and Co., N.Y., 1927) p. 65.

[2]Chapter 12.

It is precisely these oversights that enabled transcendental realism to exert such a powerful influence on scientific thought to the present day. Modern physical theories concerning superstrings, quarks, gravity waves and vacuum energy all deal with entities presumably hidden behind the veil of appearances. What scientists actually observe are such things as meter readings and data from computers; and by means of mathematical analysis they posit the existence of a myriad of noumena that are experienced by no one.

Modern quantum mechanics suggests that the physical world is of a profoundly different nature than was supposed by classical physics and the mechanistic materialism of the nineteenth century. While our theories of nature have changed radically, there has been no comparable shift in our direct experience of reality. Physicist Nick Herbert addresses this problem when he writes:

> The source of all quantum paradoxes appears to lie in the fact that human perceptions create a world of unique actualities--our experience is inevitably "classical"--while quantum reality is simply not that way at all...Since physics assures us that our lives are embedded in a thoroughly

quantum world, is it so obvious that our experience must remain forever classical?[3]

This raises an extremely important issue that leads on to a ever broader topic. Nick Herbert encourages us to question the necessity of the classical nature of our experience, with the suggestion that perhaps the quantum world can be experienced as well. We can now go on to ask: Which of the diverse, mutually incompatible quantum worlds posited by modern physicists are we to experience? The problem may be expressed in either of two ways: (1) Physicists are not really sure which interpretation of quantum theory is true of reality, or (2) many physicists are quite certain as to the correct interpretation, but they differ radically among themselves.[4]

This situation is remarkably similar to that of theologians and philosophers. But was it not the initial insistence of scientists to cut through such theoretical diversity by recourse to experience? Are we now to choose, on the basis of our metaphysical predilections, among vying interpretations of quantum mechanics, and thereafter to strive to experience what we have already decided must be

[3] Quantum Reality: Beyond the New Physics, N. Herbert (Anchor Press/Doubleday, Garden City, N.Y., 1985) p. 248.

[4] Recall, for example, the diversity of views concerning the empirical test of Bell's Theorem, mentioned at the end of Chapter 17.

true? Such an approach is certainly better described as indoctrination than as scientific inquiry into the nature of physical reality.

Modern science was founded on the basis of two incompatible themes: (1) scientific theories must be formulated such that they can be tested by experience, and (2) the physical world explained by such theories lies forever beyond the pale of experience. This is the dilemma of juxtaposing empirical science with transcendental realism.

On what grounds shall we believe in the reality of such noumena as gravity waves and the energy of the vacuum? One way that we can know things is direct experience. By such means we know such things as the colors of the rainbow, the texture of silk, and our own emotions. We know these phenomena in relation to our sensory perceptions and mental awareness; and we are not compelled to draw further conclusions as to their intrinsic attributes. Clearly, the existence of theoretical noumena has not been confirmed by such means. Indeed, the more closely one is involved in exploring the nature of such hypothetical entities, the further one is drawn away from direct experience of the physical world.

A second means of knowledge is inference. If we know, for example, that smoke can be produced only by combustion, we can infer the presence of the latter on the basis of ascertaining the former. Moreover, such inference is normally made upon already having seen combustion producing smoke. The situation for the noumena proposed by physics is quite different. We never see such entities do anything, for they are hidden from experience. Nor, from the time of Galileo onwards, have scientists been overly concerned with demonstrating that the hidden entities and processes that they propose are uniquely required to save the appearances.[5] The myriad of cases in modern physics in which diverse theories account for the same phenomena suggest that the criteria for inferential knowledge of such entities have not been met.

If the reality of the world described by physics is not known by either direct experience or inference, how is it known? In everyday life we may speak of knowing something if we have heard it from a reliable source; and in the realm of religion, believers speak of knowledge on the basis of scriptural authority. Apart from those sources, we may feel we know something simply because it is a commonly held assumption. If scientific knowledge of events beyond the realm of experience is not inferential, is it based on hearsay, authority or unquestioned belief? An affirmative answer makes a mockery of scientific inquiry; but if our reply is in the negative, a clear explanation of the means

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[5]Recall Galileo's response to this problem, as narrated in Chapter 11. The question of discovering, as opposed to creating, theoretical entities was analyzed in Chapter 15.

of scientific knowledge is needed. Unfortunately, this is hardly a common topic of discussion in science classes.

With its weird yarn of empiricism and transcendentalism, science may well have woven an intricate web of compelling fictions to replace the antiquated superstitions of the medieval era. The way to unravel the tangled knots of science and scientism must be by recourse to experience. In other words, science may need to relearn the lesson that it tried to teach medieval scholasticism: Let your theories be based upon experience, let them be tested by experience; and assiduously avoid speculating about phantoms that lie utterly outside the realm of experience.[6]

This theme challenges us to refine the quality of our own powers of awareness. There may be vast potentials for gaining much deeper, more penetrating experience of reality, which can be tapped by stabilizing and clarifying human consciousness. Here is an avenue of empirical research that Western civilization has barely begun to explore. Were it to be pursued, we might discover dimensions of reality that

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[6] One outstanding figure in Western civilization who has sought to abide by such principles in scientific inquiry is Johann Wolfgang von Goethe. Although he is remembered chiefly as a poet and dramatist, he placed great value on his innovative methods of experiential scientific research. See Goethe the Scientist, Rudolf Steiner, trans. Olin Wannamaker (Anthroposophic Press, 1950); and Goethe as Scientist, Rudolf Magnus, trans. Heinz Norden (Henry Schuman, 1948).

have lain not only beyond our previous experience, but beyond all imagination.

P A R T   F O U R:

A   C E N T R I S T   V I E W   O F
S C I E N C E   A N D   R E A L I T Y

CHAPTER TWENTY-TWO:

A PARTICIPATORY UNIVERSE

Since the time of the early Greeks, Western thinkers have sought to comprehend the physical world as it exists in its own right, apart from human experience. This quest has led to the development of modern science, which appears, at first glance, to be closing in on a complete, consistent theory embracing all of nature. A closer analysis of the realist view of science, however, indicates that our choice of interpretations of empirical evidence is invariably subject to non-scientific influences such as metaphysical preferences.[1] Thus, to declare that any one interpretation of contemporary quantum theory uniquely represents nature requires a leap of faith involving a whole string of philosophical assumptions. Yet science is widely regarded

[1] cf. Chapter 18.

as the sole means of understanding reality that does not require faith or metaphysics.

On the other hand, one may decide not to choose among any such interpretations of modern physics, but simply to regard science as a means of making correct predictions about phenomena. Such an instrumentalist view may seem to be hard-nosed pragmatism, and indeed it may suffice for an engineer or a mathematician. But it hardly provides an incentive for the quasi-religious quest for truth that Einstein thought to be an indispensable motive for the profounder sort of scientific mind.

Taking a stand on the nature of physical theory becomes problematic, with realism and instrumentalism as the two chief options. A sound view of the ontological import of physics must avoid these two extremes. It must be a centrist view that avoids the indefensible claims of realism and the barren solipsism implicit in instrumentalism. Such a view may be cultivated by inspecting more closely the natural human tendency of reification. A philosophically unreflective person tends to reify sense impressions, such as that of color, by regarding them as intrinsic to the physical objects that are experienced. A more sophisticated approach reifies only a few attribute (e.g. shape, size and mass) of the basic building blocks of nature; but those primary characteristics assumed by classical physics have been undermined by the breakthroughs of twentieth-century physics.

Still the impulse of reification carries on. Many contemporary physicists now regard the real world, independent of human experience, to be comprised of potentialities subject to the "primary qualities" of indefiniteness, chance and probability. Heisenberg in particular criticizes the realists for failing to recognize the ontological, as opposed to the mere epistemological, implications of the uncertainty principle. We should not posit the existence of that which is unknowable in principle, he declares. But he later contradicts his own injunction by positing the existence of objectively real, independent potentialities and probabilities that exist prior to measurement.

As soon as a measurement is made, the potentialities and probabilities are replaced by actualities and certainties; and physicists ponder how this obscure transition takes place. According to the centrist view that will be introduced in this discussion, such a transition has remained inexplicable for the simple reason that in reality it never takes place. It is certainly conventionally valid to speak of the existence of possibilities prior to the acts of measurement and interpretation. The fallacy occurs in reifying those potentialities as having intrinsic, independent existence and assuming that they undergo an objective shift into the realm of actualized reality.

If we are prepared to abstain from reifying even the potentia of the physical world, many problems in the foundations of physics vanish. This is not to suggest that we revert to instrumentalism, but to propose that we cease claiming knowledge about things that are in principle unknowable. The physical world as it exists in its own right, independent of direct experience and inferential knowledge is the prime example of such an unknowable.

Our experience of the physical world presents us with a potentially infinite range of possibilities of interpretation. Instead of choosing one as uniquely true of Reality (realism) or refusing to choose any of them (instrumentalism), we may adopt an interpretation of experience that makes intelligible the physical world as we conceive and experience it. In so doing, we renounce the claim to grasp reality as it exists in its own intrinsic nature and settle for the more modest aspiration to understand the world in which human beings are an integral and indispensable part. We recognize that our interpretation of empirical evidence is not determined by the "bare facts" but by the human mind.

With this centrist view, we may indeed posit the physical existence of such entities as subatomic particles, waves, energy and fields if (1) those entities can be ascertained experientially and (2) the theories in which they are conceived are internally consistent. Their existence as we define them is not inherent to a reality that is independent of our concepts,[2] but nor are such concepts "vacuous" in the instrumentalist sense of having no referents in nature. If they are verifiably conceived, they exist conventionally and physically; and as such, they are able to produce macroscopic effects.

By conceiving of a physical entity on a sound empirical and logical basis, we endow it with an existence relative to our experience and concepts. The founders of classical physics placed the human mind outside of nature, and this rejection of anthropocentrism has been heralded as one of the chief breakthroughs of Western science. Claims of understanding this mindless universe proposed by science, however, have proven to be without logical foundation. Nature does not define itself in English or German, nor does a mindless cosmos categorize itself in terms of human concepts.

In his book entitled The Character of Physical Law, physicist Richard Feynman proclaims:

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[2]The centrist view does not deny that anything exists independently of human concepts; but it does reject the belief that the human mind can conceive of anything independent of itself. More broadly speaking, nothing exists independently of the mind that cognizes it; and yet the physical world is no less real than mental events. The two exist in interdependence, and the very distinction between them is of a conventional, not an intrinsic, or absolute, nature.

> If you want to learn about nature, to appreciate nature, it is necessary to understand the language that she speaks in. She offers her information only in one form; we are not so unhumble as to demand that she change before we pay attention.[3]

Such a claim presumes that the quantities that we measure and the mathematical laws that organize them exist inherently in nature herself. But such a metaphysical stance is no more defensible than believing that our visual sensations exist independently in nature and that the cosmos was created on the basis of an English lexicon and grammar. The mathematics is an enormously useful human language, especially in providing quantitative knowledge of physical processes and in creating technology. On the other hand, it is a useless language for expressing subjective experience and for discussing the meaning of human existence. Mathematics has been an effective tool in some areas of medicine but is very limited when dealing with afflictions of the mind. In the face of the languages of other cultures and the diversity of ways of understanding and appreciating nature, the claim that nature expresses herself only in the

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[3] The Character of Physical Law, R. Feynman (M.I.T. Press, Cambridge, Mass.,1983) p. 58.

language of mathematics seems to be an extraordinarily unhumble claim.

The centrist view, in contrast to the mainstream of scientific belief, replaces human beings in the "center" of the cosmos, in the sense that we are a central, creative element of the world that we experience and seek to understand conceptually. We thus live in a participatory universe in which our existence and creative contribution can never be overlooked. While human beings are central to the universe that we inhabit, other sentient beings, such as animals and other possible beings throughout the cosmos, are central to the worlds that they experience.

Seen in this light, Western science appears to indulge in simply another form of groundless anthropocentrism: All living beings throughout the cosmos exist in the world as it is conceived by Western civilization, and insofar as their theories contradict ours, theirs are wrong; for our human concepts uniquely represent the nature of the universe as it really is. The centrist view, in contrast, suggests that not only extraterrestrial beings but other human civilizations on earth may inhabit worlds that are significantly different than that conceived by modern science. Their experience and conceptual understanding may differ from ours without either perspective invalidating the other. They simply participate in the creation of a world different from that conceived by modern Western civilization.

The idea of a participatory universe is in fact not new to Western culture. Owen Barfield goes so far as to claim that the whole basis of epistemology from Aristotle to Aquinas assumed participation, and the problem was merely the precise manner in which that participation operated.[4] Aquinas, for example, holds that a phenomenon achieves full reality (actus) only in being named or thought by man.[5]

While science was instrumental in banishing the idea of participation during the sixteenth and seventeenth centuries, it is now beginning to re-question this issue. Theoretical physicist John Wheeler, for instance, speculates that the whole universe may be a participatory, self-excited circuit. Due to "acts of observer-participancy," tangible reality may be given to the universe not only now but back to the beginning: As we observe and interpret the photons of the cosmic background radiation, we thereby "create" the Big Bang and the evolution of the universe.[6] Physicist Bernard d'Espagnat makes a similar point when he writes:

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[4] Saving the Appearances, O. Barfield (Faber & Faber, London, 1957) p. 97.

[5] ibid., p. 85.

[6] In Search of Schrödinger's Cat: Quantum Physics and Reality, J. Gribbin (Bantam Books, N.Y., 1984) p. 212.

> Our existence contributes to causing particles to emerge from a reality, which is an indivisible whole, in a (phenomenal) reality extended in space-time.[7]

Such theories presently contemplated by some physicists are associated with a theme known as the anthropic principle. It has been expressed in different ways by Robert Dicke, Brandon Carter and John Wheeler, and its central message is that our existence determines the design of our universe; and, conversely, the design of the universe makes possible our existence.[8] In the words of astronomer Edward Harrison:

> The anthropic principle asserts that the universe is the way it is because we are here...[9]

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[7] In Search of Reality, B. d'Espagnat (Springer-Verlag, N.Y., 1981) p. 97.

[8] There are a variety of interpretations of the anthropic principle, not all of which attribute any fundamental importance to the human mind. Wheeler's theory, for instance, asserts that any computer-generated measurement would suffice. This, however, raises the philosophical issue of the nature of a "measurement." If a stick falls parallel to a yardstick, is it thereby measured? If one rock rebounds off another, is the momentum of either thereby measured? Do the revolutions of an uninhabited planet about a distant star measure time? It would appear in each case that the term "measurement" is meaningful only if cited in relation to an conscious intelligence. Thus, an unconscious computer, on its own, can no more make a measurement than a yardstick can.

[9] Cosmology: The Science of the Universe, E.R. Harrison (Cambridge Univ. Press, N.Y., 1981) p. 2.

CHAPTER TWENTY-THREE:

COSMOLOGY AND A PARTICIPATORY UNIVERSE

Perhaps the chief objection to the idea of a participatory universe stems from the belief that the mind is an accidental side-product of matter. Some believe that the mind is purely a function of the brain, others seeks to equate cognitive events with neurological processes, and yet others speculate that the mind does not exist at all.[1] How then could the mind which exists at most as a mere epiphenomenon of matter play such a crucial role in the existence of the cosmos?

This objection can be countered with the fact that Western science simply does not comprehend the nature of the mind. Physical science is based upon the metaphysical assumption that the mind lies outside of nature and plays no active role in it. In the words of physicist Erwin Schrödinger:

> Without being aware of it, we exclude the Subject of Cognizance from the domain of nature that we endeavour to understand. We step with our own

[1] cf. The Ghost in the Machine, Arthur Koestler, (The MacMillan Co., N.Y., 1967).

> person back into the part of an onlooker who does not belong to the world, which by this very process becomes an objective world.[2]

Schrödinger's own view is that the world is in fact "a construct of our sensations, perceptions, memories."[3]

With its assumption of a mindless universe, physical science has developed no empirical or theoretical tools for understanding the nature of the mind. Its mechanical, quantitative means of research have yielded much information about inanimate physical processes, but they were never meant to be applied to any non-physical events. As a rule in science, to know what we are measuring, we must know the function of our measuring device. The most fundamental "measuring device" in physics is the human mind, for without it nothing would be observed at all. Yet physicists are given no training in understanding the nature of this indispensable element of their research.

Western science has frequently made use of "Ockham's razor" in cutting away presumably superfluous considerations in forming physical theories. But what elements are superfluous? What data are crucial and what are "garbage"? Once again metaphysical predilection, not nature alone,

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[2] Mind and Matter, E. Schrödinger (Cambridge Univ. Press, Cambridge, 1958). p. 38.

[3] ibid., p. 1.

comes into play. Modern Western science has assumed from the outset that the mind plays no role in nature, and this belief effectively screens out empirical evidence to the contrary.

With Ockham's razor wielded in the hand of materialism, a theory of a mindless universe is carved out, and physicists conclude that there is no evidence for the existence of any non-physical, "supernatural" mind. Such a view is as scientific and persuasive as a blind man's conclusion that there is no evidence for the existence of light. Since science lacks a coherent theory of the mind, evidence for its active role in nature is generally dismissed as "spurious" or "anecdotal"; or it may simply remain unnoticed altogether.

As physicist Eugene Wigner points out, "we do not know of any phenomenon in which one subject is influenced by another without exerting an influence thereupon."[4] Why then should we simply assume that physical phenomena influence the mind, but the relationship is not reciprocal? The notion that the mind is non-physical does not necessarily imply that it lies outside of nature or is "supernatural."

Over the history of science, various phenomena have been considered to lie outside the province of science. Until the work of Rutherford in 1911, the interior of the

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[4] Symmetries and Reflections, E. Wigner (Indian Univ. Press, Bloomington, 1967) p. 181.

atom was regarded as simply a subject of metaphysical speculation. But new tools of research were developed and it was thereby brought under close scientific scrutiny.

Many contemporary biologists similarly dismiss consciousness from the realm of natural science. Lacking the tools for dealing with it, they discard it as a mere epiphenomenon of the brain. However, rather than nurturing this ignorance of our most basic instrument of research--the human mind--it seems crucial to develop means for directly, empirically examining its nature. Most of the methods that psychology has adopted from the physical sciences do not fulfil that purpose.

The idea of a participatory universe may also be opposed on cosmological grounds. The most recent estimates of the age of the universe since the Big Bang are around seventeen billion years; and until about three billion years ago, the universe was presumably devoid of consciousness or any life-forms. Since the physical universe preceded the appearance of any sentient beings, how can its existence hinge upon participation by such beings?

Modern cosmology is based upon the assumption that mind and life are simply products of matter and energy, so it was a foregone conclusion that any theory of the cosmos would leave the emergence of consciousness as an accidental "afterthought" of inert physical processes. This is by no means the only metaphysical assumption that supports this science. Another central feature of cosmology is known as the containment principle, which states that the physical universe contains everything that is physical, and nothing else. This principle may be regarded as a mere definition or as a tautology. Any further content of that principle is of a metaphysical, not a scientific, nature.

The Friedmann equation, which is instrumental in determining the age of the universe, applies only to an idealized universe that is entirely free of irregularity. In such a uniform cosmos we are free to study any minute part in space and time and to regard that as representative of the whole.[5] This cosmic assumption is crucial for performing calculations, but on what grounds can we safely conclude that the vast reaches of the universe have such uniformity? This assumption, known as the cosmological principle, is acknowledged by astronomers to be "mostly philosophical. It has not been adequately tested, and indeed adequate tests may never be possible."[6]

The problem of multiple, incompatible theories equally accounting for the same empirical evidence is also

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[5] Cosmology: The Science of the Universe, E.R. Harrison (Cambridge Univ. Press, N.Y., 1981) p. 287.

[6] "Will the Universe Expand Forever?" J.R. Gott III, J.E. Gunn, D.N. Schramm, B.M. Tinsley in Cosmology + 1 (W.H. Freeman & Co., San Francisco, 1977) pp. 83-84.

as pertinent in cosmology as it is in particle physics. As Dennis Sciama writes in his text Modern Cosmology:

> A rigid theory has not yet been discovered. For instance, general relativity, which is the best theory of space, time and gravitation that has so far been proposed, is, as we shall see, consistent with an infinite number of possibilities, or models, for the history of the Universe.[7]

However, he follows this statement by expressing his realist assumption that not more than one of those models can be correct. There is a great element of faith here that some day a theory will be conceived that uniquely accounts for the phenomena in the one correct way. Such faith persists among realists despite the fact that the entire history of science shows evidence to the contrary.

All interpretations of the empirical data analyzed in cosmology are made upon the basis of premises that lie outside the domain of natural science. In physics these are called "principles"; the initial assumptions of mathematics are regarded as "axioms"; philosophy calls them self-evident truths; and religion acknowledges them as articles of faith. Without such assumptions, none of those branches of human

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[7]Modern Cosmology, D. Sciama (Cambridge Univ. Press, London, 1973) p. 100.

understanding would be able to operate at all. But it should be recognized that the "principles" of cosmology are no more scientific truths than are the principles of scholastic theology. On the surface of a vast ocean of metaphysical assumptions, cosmology spreads a thin film of scientific, quantitative conclusions about the entire evolution of the universe.

Medieval theologians, too, developed logical theories of the cosmos based on their own articles of faith, and the differences in the universe that they describe is, to a considerable extent, due to the differences in their initial premises. Why is it that modern cosmology is widely regarded as true, whereas non-scientific models of the universe are relegated to the status of myths? One reason is that scientists and their followers have become so committed to the belief that Nature speaks in the language of mathematics, that a theory of the cosmos that can be expressed mathematically is thereby lent greater credibility than a purely qualitative explanation. We have noted how followers of science have replaced the anthropocentrism of the Middle Ages with their own version of a human-centered view of the world. The belief that nature speaks in a human language (e.g. mathematics) may also be regarded as an updated version of anthropomorphism.

The quest to know the nature of the universe from God's perspective--to attain, in effect, divine knowledge--has been a common theme in the history of science. It may be argued that Copernicus was concerned with the movement of the planets not from an earthly, human perspective, but from an absolute, divine perspective. Similarly, Galileo considered mathematical knowledge of the physical world to be on a par with divine knowledge. This aspiration for absolute knowledge of absolute reality has persisted even among many physicists who have renounced belief in God. God may not exist, they imply, but His absolute view of reality remains; and it is for scientists to discover that view.

Such an attitude is clearly evident, for example, in Einstein's writings. On the one hand, he finds the concept of a personal God utterly incompatible with science, and even declares that such a concept is the major source of conflict between religion and science.[8] On the other hand, he declared his "firm belief, a belief bound up with deep feeling, in a superior mind that reveals itself in the world of experience."[9] This concept of God allows this superior mind to provide the absolute perspective on reality, without really influencing natural events in any way. Other physicists go a step further in rejecting any concept of God whatever, and yet persist in their belief in an absolute perspective on nature.

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[8] "Science and Religion" from Out of My Later Years, A. Einstein (Philosophical Library, N.Y., 1950) p. 27.

[9] "On Scientific Truth" from Ideas and Opinions, A. Einstein (Crown Pub., Inc., N.Y., 1954) p. 262.

As we attend to cosmology's description of the evolution of the universe from the Big Bang up to the emergence of life on our planet, a series of images of these events are brought to mind. We may imagine something like a cosmic firecracker at the beginning, red-hot gases expanding in space, the formation of radiant, bright stars, a molten, lifeless planet and finally nucleotides that mysteriously transform into living, conscious creatures.

Upon reflection, it is obvious that none of these images existed in nature, for they are human constructs based upon our conscious, visual experience. While texts on cosmology may give vivid artists' portrayals of the formation of stars and planets, such images may be profoundly misleading. They presumably depict these events as they would have appeared if humans had been on the scene to witness them. But cosmology denies that human consciousness was present, so they never looked like those illustrations. Indeed, in a cosmos devoid of consciousness, they never looked like anything at all. No images are appropriate. Nevertheless, they do come to mind; and the tendency is to reify them, to assume that they existed in a mindless universe all on their own.[1]

Before Copernicus, Western civilization assumed that Earth is physically located at the center of the universe.

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[1] cf. Saving the Appearances, O. Barfield (Faber & Faber, London, 1957) p. 37.

The Scientific Revolution challenged this view, but since then we have committed ourselves to the opposite extreme: The universe that we perceive and conceive is wholly independent of human existence, and the presence of life and consciousness in the cosmos is merely an accidental byproduct of configurations of matter and energy. This materialist view is propounded as a scientific conclusion, thereby shifting a subject--the origin and nature of life and consciousness--from the domains of philosophy and religion to that of science. Indeed, contemporary cosmology increasingly attempts to don the mantle of "divine" scientific knowledge of the fundamental issues of human existence.

Harvard astrophysicist Eric Chaisson's popular book Cosmic Dawn: The Origins of Matter and Life is particularly flagrant in its claim to displace philosophical and religious speculation with empirical scientific knowledge. Who are we? Where did we come from? How do we relate to the rest of the Universe? What is our destiny? What are the origin and destiny of the Earth, the Sun and the Universe? All of these questions are purportedly being resolved by contemporary scientific research and dramatic technological advances.

What, according to this view, is the nature of human existence? We are each a cluster of genes inherited from our many ancestral life forms, which is shaped by our environment. How did life originate? The author narrates the two major views of modern scientists: (1) Since life on Earth depends on just a few basic molecules, life throughout the cosmos may be common due to the commonness of those molecules, and (2) "intelligent life on Earth is the product of inconceivably fortunate accidents--astrophysical and biochemical mistakes that are unlikely to occur anywhere else in the Galaxy or the Universe.[2]

Both of these views are seen to be utter speculation as one scrutinizes the evidence scientists have to deal with. For example, the author admits that "the distinction between matter and life is not clear-cut; it's fuzzy because life itself is nearly impossible to define."[3] Although the origin of life is said to be a natural consequence of the evolution of atoms and molecules, laboratory experiments have yet to fashion anything more sophisticated than life's precursors. Biochemists have formed a consensus that life evolved purely from matter and energy within the special field of study of biochemistry, yet they do not really know how life actually emerged from inert substances. In other words, despite this lack of knowledge, there is conformity of belief as to the origin of life in the Universe.

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[2]Cosmic Dawn, E. Chaisson (Little, Brown and Co., 1981) p. 292.

[3]ibid., p. 165.

Chaisson speculates that pre-biological substances probably found shelter from solar ultraviolet radiation on earth; and from that point on "biologists can only presume that at least one proteinoid-like amalgam was eventually able to evolve into something everyone would agree is a genuine living cell."[4] Chaisson points out, however, that nothing yet discovered in the fossil record documents this pre-life evolutionary phase.

Thus, in seeking to understand such events as the origin of life, modern science concerns itself solely with physical evidence such as fossil records and biochemical processes. Obviously, before the first twentieth-century research was conducted, scientists had already adopted a uniform metaphysical assumption that the only influences on life's origins were of a physical nature. This consensus derives directly from the popular mechanistic materialism of the last century, which was no more truly scientific that its present incarnation. Most astonishing of all, biochemists lack any conclusive, physical evidence as to how life emerged, and yet we are still led to believe that their musings count as scientific knowledge in place of philosophical and religious speculation.[5] Once again,

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[4] ibid., p. 187.

[5] cf. Cosmology: The Science of the Universe, E.R. Harrison (Cambridge Univ. Press, N.Y., 1981) p. 390. The point here is not to place scientific inquiry into the origins of life on the same plain as all theological and philosophical speculation. Such notions by theologians and philosophers are often devoid of

scientific ignorance describes what "probably " happened "by accident."

Biology displays a similar ignorance as to the nature of consciousness. This, however, does not prevent it from stating unequivocally that "the body's nervous system, of which the brain is the paramount part, controls all mental and physical activity. In fact, every thought, feeling or action begins in the brain."[6] Chaisson states that the first animals--the earliest ancestors of humans--appeared less than a billion years ago. Noting this, our interest may quicken as we seek an answer to the ultimate origins of consciousness in the universe; for if those first animals were our earliest ancestors, it must have been in them that consciousness first arose. The stupendous, cosmic event of the origins of consciousness unfortunately slipped by unnoticed in Chaisson's account of the universe. The subject is never addressed, and consciousness is vaguely

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any empirical basis accessible to human beings, and they provide no program for further investigation. Scientists theorizing about the origins of life do have some empirical basis--be it ever so partial--and they do have an avenue for further research. The point of the above argument is that the type of evidence that biochemists seek is already largely determined by their preconceived metaphysical beliefs. While such assumptions suggest some programs for further investigation, they refute the value of others that might be at least as eluminating as the ones they do follow. Those same metaphysical beliefs then exert a strong influence on the manner in which empirical evidence is interp e

[6] Cosmic Dawn, p. 199.

attributed to a certain "complexity" of configurations of matter and energy.[7]

As science has distanced itself from the medieval notion of an anthropocentric universe, it has identified itself with a diametrically opposite metaphysical stance: Human existence has no place in the universe at all. Life itself is an insignificant accident in terms of the cosmos as a whole, human existence is a matter of genes dominated by environment, and consciousness has no existence at all apart from certain neurophysiological processes. Chaisson encourages his readers to regard such cosmic evolution as "wonderfully warm and enlightening,"[8] but many other scientists and non-scientists are more drawn to the conclusion of physicist Steven Weinberg: "The more the universe seems comprehensible, the more it also seems pointless."[9]

The concept of a participatory universe is fundamentally incompatible, not with scientific knowledge of the cosmos, but with the mechanistic materialism that is still so prevalent in modern cosmology and science as a whole. Participation implies an interaction between consciousness and its objects,and insight into the nature of

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[7]ibid., p. 199.

[8]ibid., p. 299.

[9]Cited in Superforce, P. Davies (Simon & Schuster, Inc., N.Y., 1985) p. 222.

such participation requires knowledge of both the mind and the physical world. Natural science has illuminated many facets of physical reality, but it has kept us completely in the dark as to the nature of consciousness. Moreover, in failing to acknowledge its own metaphysical bearings, it proclaims its materialist biases as scientific conclusions; and it proclaims its ignorance of the non-physical as knowledge that only the physical exists. A science that claims the entire cosmos as its domain must seek knowledge of all facets of reality. As Edwin Burtt commented in his book The Metaphysical Foundations of Modern Physical Science:

> An adequate cosmology will only begin to be written when an adequate philosophy of mind has appeared...[10]

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[10]Cited in Cosmology: The Science of the Universe, p. 118.

CHAPTER TWENTY-FOUR:

SCIENTISM AND FUNDAMENTALISM

The foregoing chapter and various other discussions in this work may easily be regarded as an attack on science, as one more skirmish in the battle between science and the humanities, or science and religion. In fact, no such disparagement of science was intended, any more than a physician, while discussing cancer, intends to denigrate the victim of this disease. An affliction that has embedded itself in much of science has come to be known as scientism. Peter Medawar describes scientism as follows: "the belief that science knows or will soon know all the answers, and [that belief] has about it the corrupting smugness of any system of opinions which contains its own antidote to disbelief."[1]

Scientism can be more fully understood when it is recognized as being one manifestation of a more basic mentality. Another branch stemming from this diseased root is religious fundamentalism. In fact, many of the apparent disputes between science and religion are actually battles between scientism and religious fundamentalism. Each claims

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[1] Pluto's Republic, P. Medawar (Oxford Univ. Press, N.Y., 1984) p. 60.

for itself sole propriety of truth and denounces the other as myth or prejudiced fabrication, and there are many other striking parallels between the two. A similar mentality may express itself in the realm of philosophy as well, and the common denominator may be called exclusive absolutism.

Such an absolutist attitude claims that "the facts speak for themselves," without need of subjective interpretation. Empirical scientific evidence when subject to mathematical analysis describes Nature as it is; the statements of scripture are God's own words, whose meaning is self-evident; and philosophical absolutism has its own set of a priori facts and self-evident empirical truths. All feel that their system of belief captures the nature of absolute reality and that any other approach is invalid. After all, Reality (Nature, God, Truth) speaks only in the language of that doctrine. Arrogance, intolerance and self-complacency are all common symptoms of this malady.

Absolutism may encourage critical thinking among its followers, but only within the narrow confines of its articles of faith. It gives completely free reign to criticize and condemn other systems, without any obligation to understand them. All one needs to know is that they are not the one true way, and this allows one to denigrate them without any knowledge of their real content.

Both scientism and religious fundamentalism discourage their followers from engaging in critical investigation of the historical roots of those disciplines. Diversity of opinion within the ranks is concealed, as are the succession of historical influences on the formation of the present creed. Historical reflection is discouraged, for it may lead to a recognition that the doctrine does not derive simply from Nature or God, but from the human mind as well. Such an insight tends to undermine the absolutist claims of this mentality. Philosophical reflection is also disparaged. The advocate of scientism insists that scientific methods alone can yield knowledge of the foundations of science and its methodology; and the fundamentalist poses revelation, prayer or other religious practices as the sole means to understanding.

Both forms of absolutism regard their respective doctrines as essentially complete explanations of the whole of reality, so anything outside of the system is discarded as irrelevant or non-existent. Early Christian fundamentalism, for example, regarded the gods of earlier religions as unworthy of worship; and this attitude gradually changed to the point of denying their existence altogether. Scientism initially regarded God as being outside of Nature and the sphere of science, and later proceeded to reduce this peripheral status to that of a non-entity. It takes a similar attitude toward the existence of the mind.

Absolutism must have evangelists, and their task is to persuade, to indoctrinate, to convert, and not to stimulate critical thinking in their audience. They are power-brokers, not truth-seekers, and their goal is to empower their organization to dominate people and their environment at large. Physicist John Taylor sums up this view nicely when he writes: "The scientific approach is the only reasonable way to acquire an ever increasing understanding of nature, and one that has proved itself by bringing mankind awesome powers."[2] Astrophysicist Eric Chaisson gives this attitude cosmic proportions in the closing sentence of his book Cosmic Dawn: "We may eventually gain control of the resources of much of the Universe, redesigning it to suit our purposes and, in effect, ensuring for our civilization a sense of immortality."

In their campaign of conversion, absolutists may feel compelled to simplify or even distort the truth as they see it in order to make it acceptable to devotees. Astronomer Edward Harrison comments that in popular literature the recession velocities and distances of galaxies are "usually not stated within the context of a particular cosmological model or hedged with reservations concerning the validity of the model, for fear of puzzling the audience and losing its

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[2] The New Physics, John G. Taylor (Basic Books, Inc., N.Y., 1972) p. 7.

interest.[3] This suggests that it is preferable to dupe the public into unquestioning belief and wonderment rather than leave them in doubt as to the absolute authority of science. The Doppler formula, for example, allows the astronomer easily and quickly to make statements about recession velocities and distances, but in many cases those statements are meaningless in cosmology. Their only virtue, according to Harrison, is that they capture the interest of the public.

Scientism and fundamentalism both tend to devalue subjective human experience. Both claim to have access to a transcendent reality that can only be known by its unique methods; and that reality may have little in common with the individual's own experience. When confronted with internal inconsistencies in the realm of quantum mechanics or theology, for example, the absolutist is quick to challenge the authority of the logic that identifies them. Such subjects are posed as "mysteries," and they are to be accepted with faith and the abnegation of one's own common sense. In short, absolutism debases the subjective experience and intelligence of the individual, making him or her a suitable tool of the organization and its creed.

For further indication of the similarity between scientism and religious fundamentalism, it is worth noting

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[3] Cosmology: The Science of the Universe, E.R. Harrison (Cambridge Univ. Press, N.Y., 1981) p. 239.

that it is not uncommon for people of that mind-set to adopt both forms of absolutism, despite their differences of content. Such a mentality is not prone to critical reflection, and this trait allows it to divide the world into two realms: Scientism accounts for the physical world, and religious fundamentalism sets the standard for values and the road to salvation. Thus, the mind of such an absolutist is neatly bifurcated, and due to lack of reflection, internal inconsistencies are overlooked. Absolutists are also strongly inclined to condescension and ridicule of views contrary to the one true doctrine, and with missionary zeal they seek to root out "pseudo-scientific beliefs" and "pseudo-religions." They display no interest in truly understanding opposing views, only in condemning them.

On a broader front, this attitude may bear the symptoms of cultural chauvinism. From the time of its origins, Western civilization has traditionally regarded alien peoples as barbarians and pagans. Europe and its former colonies thus don the mantle of the one true civilization.[4] Such an attitude is prevalent even among many of the finest thinkers of the modern world. Will and Ariel Durant's classic ten-volume set entitled The Story of Civilization

[4]European civilization hardly has a monopoly on such cultural chauvinism; it is also promoted by other societies, each with its own grounds for asserting its uniquely superior status among the diverse peoples of the world.

devotes nine volumes entirely to Western civilization. The remaining volume is entitled Our Oriental Heritage, suggesting by its very name that the civilizations of Asia should be regarded as more primitive precursors of that of the West. Similarly Frederick Copleston's nine volumes of A History of Philosophy contains no reference to any of the world's philosophies that do not derive from Greek thought. Likewise, science is portrayed as a unique product of Western civilization, and most accounts of Western religions emphatically proclaim their exclusive validity.

Thus, absolutism in the form of cultural chauvinism suggests that our civilization is the only one worthy of the name, and it has a monopoly on philosophical, scientific and religious truth. Not only does it absolutize these bodies of knowledge, it does the same to the boundaries that set them apart as distinct avenues of understanding. Thus, when Western absolutists do look into Eastern knowledge, they immediately try to classify it in terms of these three categories. This tendency is due to an ignorance of the fact that this triad of science, philosophy and religion, as we define these disciplines, is purely a creation of Western civilization. Classical India, for example, did indeed develop fields of knowledge corresponding to this triad; but, unlike modern Western civilization, it did not treat them as autonomous, disjunct disciplines. But Western absolutists insist that Reality demands that knowledge be classifiable according to its own conventions. Thus, Will Durant writes condescendingly that "India drowns philosophy in religion,"[5] while in fact the very imposition of the Western concepts of philosophy as opposed to religion are inappropriate outside the context of Western civilization.

Finally, cultural chauvinism, scientism and fundamentalism all claim, predictably enough, to have the sole solution for the world's problems. The first promises world salvation through civilizing all societies according to our own standards. Scientism promises scientific and technological solutions to the military, economic, environmental, social and even moral crises facing humankind; and fundamentalism claims that the world's problems can be solved only by subjugating everyone under the one true faith. Absolutism abhors diversity and seeks to extinguish competing views, values and modes of conduct. While presenting itself as the sole cure for the ailments of humankind, it is in fact one of its most malignant afflictions.

Western civilization hardly has a monopoly on such absolutist mentalities; they are common in other societies as well. Our civilization does indeed have major contributions to make to human society as a whole in terms of our unique sciences, philosophies and religions. But a

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[5] Our Oriental Heritage, Will Durant (Simon and Schuster, N.Y., 1935) p. 936.

planetary culture can be nourished only when we recognize that no society or body of knowledge has a unique access to reality. In a participatory universe we are responsible for the world that we help to create, and it is the duty of those who recognize this to make a world that is safe for diversity. Only then can we most fully explore the reality of which we are an integral part.

CHAPTER TWENTY-FIVE:

CONCEPT AND EXPERIENCE

The absolutism discussed in the preceding chapter is a gross derivative of a mental distortion we have called reification. In reifying or absolutizing the world around us, we assume that there is an absolute perspective on the universe, as it exists in its own right. In the West this assumption presumably stemmed from belief in an omniscient God, but it has persisted even among many thinkers who regard themselves as atheists. Like the Cheshire cat who leaves only his grin behind, God is sent offstage, but His absolute perspective lingers on.

The centrist view flatly denies the existence of absolute reality in the sense of anything existing intrinsically, by its own independent nature; and it refutes any absolute perspective on the universe. Thus, insofar as cosmology, for example, attempts to describe the evolution of the cosmos from the perspective of what occurred absolutely--independent of concept and experience--it deals in pure fiction; for no such absolute series of events in nature ever took place.

Realism assumes that the objects and events in nature define themselves in ways that can be grasped by the human mind, e.g. through the language of mathematics. Einstein expressed this view in his comment that the most incomprehensible thing about nature is that it is comprehensible. The centrist view, on the other hand, denies that physical reality defines itself in terms of mathematics or any other human language or concepts. In short, nature does not define itself at all. If objects and events in nature did define themselves, if every entity intrinsically bore its own attributes and were absolutely demarcated from other entities, it would seem that only one language that could represent the world. Definitions of subatomic particles, animals, utensils and so on would be exclusively determined from the side of those objects. "Theory" would indeed be derived solely from "observation." All the languages of the world, insofar as they accurately represent reality, would have to be composed of terms that were precisely inter-translatable.

Any linguist knows that this is not the case. Definitions of terms, grammar, and syntax all vary widely among languages; and often the more distant the roots of two languages, the more pronounced are the differences between them. The axioms, definitions and rules of mathematics also vary from one system to another, as is true of other systems of human logic.

Human beings define the objects and events of the world that we experience. Those things do not exist intrinsically, or absolutely, as we define them or conceive of them. They do not exist intrinsically at all. But this is not to say that they do not exist. The entities that we identify exist in relation to us, and they perform the functions that we attribute to them. But their very existence, as we define them, is dependent upon our verbal and conceptual designations. Thus, the world that we experience is related to human language, and the fact that it is humanly comprehensible presents no mystery at all. On this subject Benjamin Lee Whorf writes:

> The idea, entirely unfamiliar to the modern world, that nature and language are inwardly akin, was for ages known to various high cultures whose historical continuity on the earth has been enormously longer than that of Western European culture.[1]

Everything in the world that we conceive of and experience is related to the human mind. When that world is reified, however, it appears to exist absolutely, in its own right; and this mental distortion may lead one to wonder how nature can be comprehensible to the human mind. Einstein, who routed absolute space and time from the universe, still

[1] Language, Thought and Reality: Selected Writings of Benjamin Lee Whorf, ed. J.B. Carroll (M.I.T. Press, Cambridge, Mass., 1966) p. 249.

grasped onto an absolute ontology. Another term for the centrist view presented here might be <u>ontological relativity</u>, and it fundamentally challenges the realist ontological assumptions underlying virtually all of Western science. Theory, in the form of conceptual designation, permeates our experience. As theory is not determined by some intrinsic nature of reality, there is no one conceptual system that uniquely accounts for the myriad of natural phenomena. Objects exist relative to the theory-laden consciousness that experiences them, and any consciousness exists relative to the events that it cognizes.

From the centrist perspective, ontological absolutism is based on the mental distortion known as reification. The process of reification in science is quite similar to that same tendency in everyday life. This stands to reason, since scientific inquiry itself bears so much in common with ordinary mental activity. Einstein made the following distinction between the two:

> The scientific way of forming concepts differs from that which we use in our daily life, not basically, but merely in the more precise definition of concepts and conclusions; more

painstaking and systematic choice of experimental material; and greater logical economy.[2]

Another distinction, however, is that reification in science expresses itself in terms of transcendental realism, whereas that mental habit it daily life might be called immanent realism.[3] In the former case, scientists reify the existence of noumenal entities that lie behind appearances. Thus, subatomic particles, electromagnetic fields and the zero-point energy of the vacuum are assumed to exist independently of the experimental data on which they are based, and independently of the theories in which they are conceived.

Immanent realism looks upon the world that is perceived with the senses and assumes that it exists in its own right just as it appears to us. It ignores the role of both sensory perception and conceptual imputation in our experience of phenomena and, thus, naively concludes that they exist independently of any subjective influence. In terms of daily life experience, followers of science are also prone to this tendency. They are thus subject to both forms of reification: immanent and transcendental.

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[2] "The Fundaments of Theoretical Physics" from Out of My Later Years, A. Einstein (Philosophical Library, N.Y., 1950) p. 98.

[3] It is often known as "naive realism," and this has come under the attack of such thinkers as Democritus, Descartes and Galileo, all of whom posited the existence of primary and secondary properties of the world.

Both in scientific research and in everyday experience we ascertain objects that are endowed with certain attributes, and it is by means of the defining characteristics of an object that we identify it. A major tenet of the centrist view is that entities do not determine their own defining characteristics; i.e. they are not self-defining. Having recognized a certain object, we say that it has the qualities by which we identify it. What is the relationship between the object and its various attributes?

Let us focus for the moment on a physical entity and assume, in accordance with the realist view, that it and its attributes exist intrinsically, independent of conceptual designation. Take, for example, a proton: It has a certain mass, charge, size and according to present theory it is made up of quarks. Is the proton identical with any one of those qualities or parts? Is it, for instance, identical with its mass? If so, is it really suitable to say that the mass of a proton has a charge? Might we not equally say that the proton is its charge, and that its charge has a mass? Actually neither statement is true of physical theory. A proton has mass and charge, but it is identical with neither. Nor can it be equated with any one of its component quarks, for it would be pointless to say that one of its quarks <u>has</u> the others.

We might easily equate the proton with the set of all its attributes and parts, for it is true that this set does have all the characteristics of the proton. However, the qualm arises: Is the proton not endowed with the set of all its attributes? If it does have that set of attributes, it is difficult to assert that it is that set. How can anything be identical with something that it has? If this were possible, we would have to assert that a proton has itself, but this suggests that for every proton there would be two protons: the particle that has the complete set of its attributes, and the particle that is the complete set of those attributes.

A second problem is that if something is identical with a proton, everything that is true of the latter must be true of the former. Let us take the event of two protons colliding.[4] When they do so, one side--let us say the "north side"--of one proton strikes the "south side" of another. When that happens, we correctly state that one proton struck another. Is it equally correct to say that the complete set of attributes of one proton struck the complete set of the other's attributes? The "complete set" obviously includes all the attributes and components; but it

[4]This example is assuming a simplistic model of the proton as a clearly defined, real particle, without any of the problems introduced in quantum mechanics, such as the wave/particle duality and the uncertainty principle. Since this model of the proton still plays a strong role in scientific thinking and teaching, it is not irrelevant to introduce it in this argument.

is not true that the "west sides" of both particles struck one another.[5]

Finally, what is the nature of this "complete set of attributes"? It is not identical with any one of its components. In fact, it seems to be a prime example of a conceptual designation without any independent referent in physical reality. Thus, if the proton is identical with that set, it too must have no independent existence.

Alternatively, we might posit that the proton is identical with a few of its attributes, such as its mass, charge and size. However, these three entities are mutually exclusive: There is nothing that is the mass of a proton as well as its charge and size. This would be like saying that there is one thing that is the hoof of a camel as well as its tail and its head. Those three entities have very different characteristics, and there is nothing that can be all three. Certainly a camel is not its hoof, any more than a proton is its charge.

In short, the proton cannot be equated with any one or more of its attributes, nor is it identical with the set of all its attributes. It has those characteristics, but it is none of them. Does a proton exist intrinsically apart from

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[5]If this argument is not so clear-cut with respect to the quantum mechanical view of the proton, it may be due to the fact that this more contemporary view is far from clear-cut. Insofar as quantum mechanics differs from classical physics in terms of its ontological implications, it appears to lend greater support to the centrist view than to transcendental realism.

all its components? If so, it should be possible to remove all of them, leaving the proton on its own. But a proton devoid of mass, charge, size and so on can hardly be called a proton, nor can it perform any of the functions of a proton.

If a proton does not intrinsically exist either among its parts or separate from them, the inevitable conclusion seems to be that it does not intrinsically exist at all. We must hasten to add that this statement does not imply that protons and the myriad of other subatomic entities described by particle physics have no existence whatever. If such entities can be experientially ascertained and if the theories in which they are proposed are internally consistent, they do exist and are identified by their defining characteristics. But they do not exist independently of the theory in which they are introduced. Rather, they exist by the power of conceptual designation, and their existence is of a conventional, not an absolute nature. As such, they are still able to perform all the functions that we attribute to them.

A major attribute of modern Western science has been that it has continuously sought to expand and refine our experience of physical reality by means of increasingly sophisticated instruments and experiments. Thus, a physical theory based on present experience may not accord with later, more revealing, experimental evidence. How then can we establish that our physical theories accord with experience, when we do not know what future research will bring to light? We can confine the scope of our theories to our present experience, without generalizing that they are valid for all possible experience. In this way they can be regarded as conventionally valid within the context of our experience, and they are left open for modification in light of new empirical discoveries.

The centrist view denies any artificial ontological demarcation between the world of particle physics and the world of everyday experience. A large quantity of particles in a certain configuration certainly may be able to perform functions that the individual particles cannot; but this can hardly imbue it with a more concrete ontological status. If the basic components of the physical world lack intrinsic existence independent of conceptual designation, the same must be true of the physical universe as a whole. Thus, if the elementary particles of which the physical world is composed do not exist independently of conceptual designation, there can be little doubt that macroscopic configurations of such particles similarly lack independent existence.

If one accepts this conclusion, it would be very easy to slip off into a form of idealism, positing mind alone as the absolute reality. The centrist view, however, assiduously avoids this extreme. A physical process exists in dependence upon three factors: (1) its own components, (2) other causally related physical and mental entities and (3) the mental designation of that process. Similarly, a cognition of a physical process depends upon (1) its own components, (2) other causally related mental and physical entities and (3) the mental designation of that cognition. Physical and mental events are mutually dependent, and neither are more real than the other.

The preceding analysis suggests that a proton is conceptually designated upon its attributes, and neither the proton nor its components exist independently in physical reality. The charge of a proton, for instance, can no more exist independently of the proton than the proton can exist apart from it. Moreover, both are also dependent upon the conceptual designations of them. Is the case fundamentally different for a subjective sensation, say a visual image? This sensation, too, has various qualities. Following the same line of reasoning as above, can a visual image be equated with any one or more of its characteristics? The previous analysis still applies. The image cannot be equated with any of its attributes, nor does it exist intrinsically apart from them. It, too, is conceptually designated upon its defining characteristics, and it is neither ascertained, nor does it exist, apart from them. The boundaries that set such sensations apart from other entities are not determined by Nature; i.e. they are not intrinsic to those entities themselves. Rather, they are imputed by language and concepts. In the words of Benjamin Lee Whorf:

> Each language performs this artificial chopping up of the continuous spread and flow of existence in a different way.[6]

Is the situation any different for consciousness itself? The various types of sensory and mental consciousness all have their own characteristics. The awareness, or consciousness, of a visual image, for example, has certain qualities by means of which we recognize it. A continuum of sensory awareness also has parts in terms of its being composed of a series of extremely brief moments of cognition. That continuum is not identical with any single instant of awareness. Is this awareness equivalent to the sum of all of them? This cannot be, for the sum total of those moments does not exist at the time of any one of those instants; yet it would be absurd to say that awareness does not exist at the time of any single moment of awareness.

A single finite moment of awareness also has parts: It must have a beginning and an end, otherwise it would have no

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[6] Language, Thought and Reality: Selected Writings of Benjamin Lee Whorf, p.253.

duration. But it is not identical either to its beginning or its end, nor can it be both, for they exist at different times. A moment of cognition <u>has</u> a beginning and an end, but it is equivalent to neither. Nor does it intrinsically exist apart from its temporal components. As mentioned above, a moment of cognition also has various defining attributes that set it apart from other entities. Without analyzing those specific characteristics, it still holds that such cognition <u>has</u> those properties; and as such it is conceptually designated upon them. This suggests that the demarcations between awareness and other entities are not determined by their own intrinsic nature. Rather, the conceptual mind defines such entities and, having done so, imputes them upon bases of designation that are never identical with those entities.

What of the conceptually designating mind? Does it have a different ontological status from the other entities that it identifies? The answer must be in the negative, for it, too, has attributes; and it is neither identical with them nor intrinsically separate from them. The same must be true of the person whom each of us designates as "I." I am conceptually designated upon my body and my mind when I say, "I am tall," or "I am alert." I have a body and a mind, but I am identical with neither. Nor do I intrinsically exist apart from them. Rather I am conceptually designated upon my body and/or mind at various times, and as such I am able to perform actions that are attributed to me.

An intellectual man is likely to identify himself with his mind: "I think, therefore I am; the thinker is I, therefore the mind is I." However, that person may also think at times, "I am overweight" or "I don't get enough exercise." If he is in fact the same as his mind, it must follow that his mind is overweight and does not get enough exercise. But of course it is his body that is overweight, and his mind may be getting too much exercise.

One who is inclined to philosophical speculation may respond to this problem by replying: "Actually I am my mind. Other uses of the term 'I'--such as 'I am tall'--are simply conventions referring to my body." In this way one may simply exclude common usages of the term "I" that do not conform to one's self-concept. In so doing, philosophy is divorced from everyday language, thinking and behavior. Phrases like "You are looking cheerful today" must now be considered inaccurate; for "you" are identified with "your mind," and "your mind" does not look like anything today, cheerful or otherwise.

The mystically inclined may go a step further and identify the "I" as something independent of both the body and mind. In this case, I have a body and a mind; but now statements like "I am feeling ill" and "I cut myself" must be regarded as inaccurate. Such an "I" can be affected by nothing, nor can it engage in any action; for invariably actions are performed with the body and/or the mind.

A more common notion is to consider the complete set of one's attributes of body, mind, behavior and personality as "I." This self-concept also invalidates most of the conventional usages of the term "I." I cannot see you, for I cannot see the complete set of your attributes. I am not tall, for the complete set of my attributes is not tall. Moreover, I can no longer say that I have a complete set of personal attributes, for if I am one and the same as that set, I cannot have it.

The centrist view seeks to understand the nature of the "I" that thinks of itself and refers to itself and others according to the conventions of language. This is the "I" that we are all concerned with on a daily, practical basis. A self-concept that invalidates common usage of the term "I" makes itself irrelvant to daily life. Thus, the centrist view adheres closely to convention and concludes that the "I" is not the same as the body, the mind or the set of all personal attributes; nor is it truly separate from them. Rather, the "I" is designated at various times upon the body, the mind, and the body-and-mind; but it is identical with none of them.

Having inquired into the ontological status of the physical world, mind and the "I," let us move on to the nature of time. Any instance of time has duration. We may speak of the age of the universe or the time that it takes for light to traverse the diameter of a proton--each segment of time has a duration such that its beginning is not simultaneous with its end. Such a period therefore has a beginning and an end. It is not identical with its beginning; otherwise it would not exist at its end, and vice versa. Since it is not its beginning or its end, it cannot be both its beginning and its end. One might hypothesize that it is the same as the complete set of its beginning, middle and end. However, in that case, it would not exist at its beginning, middle or end; for that complete set is not present at any of those times. It has a beginning, middle and end, but it does not exist independently of them; otherwise it could exist in their absence.

Once again we are led to the conclusion that any period of time is conceptually designated upon something that is not it. It is not findable under analysis, so we conclude that its existence is purely conventional. The central view denies the existence of absolute time, either with respect to physical or cognitive events. Time as it is conceived by the human mind does not exist in some independent, objective world; it exists only in relation to the mind that conceives it.

What is the centrist view of space? Any region of space, from the volume of a quark to the expanse of the entire universe has extension. From a given perspective it has a frontside and a backside, and the two are not the same. Analysis similar to that presented in the above cases demonstrates that a region of space is not identical with any of its parts, nor with the complete set of its parts. If it were the same as the complete set of its parts, it would never be possible for a body to enter that space; for it is impossible to enter all its parts simultaneously. The body would have to enter the front before it got to the back. Clearly, it is meaningless to speak of space as independent from all its parts, so we once again conclude that space is not absolute: It exists in dependence upon mental designation.

This conclusion holds equally for the modern concept of spacetime. If it has no parts or attributes, it must be forever unknowable, in which case there is no reason to posit its existence. If it does have parts, we can apply the same "whole and parts" analysis, and it leads us to the same conclusion: If spacetime, as it is conceived in the general theory of relativity, does exist, it is a conventional reality only. Ontologically speaking, there is no absolute space, time or spacetime. Even a casual study of Einstein's relativity theories can leave no doubt that his rejection of absolute space and time is of a different kind than the refutation presented here. The centrist view refutes not only the absolute space and time of classical physics, but the absolute spacetime of relativistic physics.

Spacetime as conceived by Einstein may indeed exist, but as a conventional, not an absolute reality.

In like fashion, if the existence of the zero-point energy of the vacuum were to be experientially verified--be it of zero, finite or infinite magnitude--similar analysis would be applied. Such vacuum energy would not be one with its parts or attributes, nor would it be intrinsically separate from them. If it intrinsically possessed its own parts, the demarcations between it and other entities would exist intrinsically and therefore absolutely. In that case, there could be no interrelation between the vacuum energy and matter, for instance. They would be absolutely separate and could in no way influence one another. Thus, if the vacuum energy exists, it is a conventional reality. This by no means implies that its existence is arbitrary, or that its interactions with other events are not subject to physical laws. Physical processes and the natural laws that "govern" them are of a conventional nature only in the sense that they do not exist independently of conceptual designation. The laws of physics, for example, are precisely determined by means of experiment and observation. They are not simply creations of arbitrary human whim. However, they have no independent existence. Such laws are dependent upon the events with which they are concerned. The gravitational inverse-square law, for instance, has no existence independent of matter; nor does that law, as conceived by human beings, exist independently of human conceptual designation. Its existence is relative, not absolute.[7]

The centrist view regards not only physical laws but the rules of mathematics and, more generally, logic as being of a conventional, not an absolute nature. Once again it must be emphasized that this does not necessarily mean that they are arbitrary. They occur to the human mind in dependence upon our interactions with our environment. They are not created simply by whim. Thus, mathematics and qualitative logic can both be extraordinarily useful tools in probing the nature of reality; but the truths that they reveal do not exist independently of the intelligence that discovers them. Any philosophical system that devalues the rules of logic as being purely arbitary must be self-defeating; for it must have some reasons--and therefore some logic--in support of this position. And any conclusions that such a system draws must therefore also be regarded as arbitrary.

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[7]This same point can be made with reference to ethical laws. Buddhist contemplatives identify as unethical various types of mental, verbal and physical actions. These actions are motivated by such mental distortions as ignorance, hostility and craving, and they result in suffering for oneself and others. There are natural laws "governing" the manner in which wholesome and unwholesome actions lead to well-being and suffering. They are "objective" in the sense that they are not subject to human whim; but they are "conventional" in that they exist as dependently related events, rather than as absolute things in their own right.

We may focus finally on reality as a whole, what Whorf perhaps had in mind when he wrote of the "continuous spread and flow of existence." Does the whole of reality, without making any distinctions between mind and matter, matter and energy, or microworld and macroworld, exist in its own right, independent of conceptual designation? We may ask first: Is such a reality posited as having parts or attributes? Is it made up of all the atoms, minds, galaxies and spacetime of the universe, or does it exist apart from them? If it is made up of such components, we may apply the same analysis as above and arrive at the same conclusion: Reality as a whole is also a conceptual designation. If the Whole intrinsically exists apart from all the components of the known universe, this implies that it would remain even if the universe as we know it were to vanish. But such a Cosmic Totality sounds more like a useless metaphysical appendage to reality rather than something that bears any meaning for those living in the universe.

By means of such analysis we can inspect anything that is conceived as being existent, and in each case we find that that entity is known by certain defining characteristics. It has those attributes and cannot be equated with them. Under such analysis, nothing can be found that exists in its own nature, independent of conceptual designation. Everything is "empty" of such an intrinsic identity, and that "emptiness" may be regarded as its essential nature. Perhaps the physicist Louis de Broglie had some intimation of this truth when he wrote:

> May it not be universally true that the concepts produced by the human mind, when formulated in a slightly vague form, are roughly valid for Reality, but that when extreme precision is aimed at, they become ideal forms whose real content tends to vanish away? It seems to me that such is, in fact, the case...[8]

When phenomena are not closely examined, they seem to exist in their own nature, independent of conceptual constructs; but when the preceding type of analysis is applied to them, they seem to vanish away.

Although all things, physical, mental and otherwise, are devoid of an intrinsic nature, they still exist on a relative, or conventional level, and this is sufficient for them to interact with other entities. Neither physical nor mental events are more "real" than the other; neither bears an absolute existence; so the centrist view is neither materialist nor idealist. The emptiness of an intrinsic nature of all phenomena is itself not an absolute; it, too, lacks an intrinsic nature; so this view also escapes the

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[8] Matter and Light: The New Physics, Louis de Broglie, trans. by W.H. Johnston (W.W. Norton, N.Y., 1939) p. 280.

extreme of nihilism. The logic by means of which such conclusions are drawn is also not grounded in absolute reality. It is considered to be valid, but its authenticity is of a conventional, not an absolute or an independent nature.

The centrist view certainly does not accord with realism, as it has been described in the preceding chapters, nor does it adopt the tenets of instrumentalism. Insofar as scientific theories are internally consistent and are verified by experience, the events that they describe are granted conventional reality. They do not exist independently of those theories, but neither are they purely mental creations with no referents in physical reality.

Physics offers us bodies of experimental evidence which can be consistently interpreted in a variety of ways. We may choose among such competing theories and gradually incorporate our choice into our view of physical reality. Western physics, however, does not offer the only valid possibilities for interpreting the nature of the physical world. It has devised a certain approach to gathering empirical evidence of physical events, namely the use of mechanical instruments. Other cultures, such as that of classical India and Tibet, have devised other approaches entailing the refinement of human consciousness as a means of empirically investigating physical reality. The evidence that those cultures have brought to light is quite different from that revealed by the means of Western science, but it is no less authentic. Their approach is chiefly qualitative; that of physics is chiefly quantitative; and neither has an exclusive claim to validity. In short, on the basis of evidence not presently known to Western science, alternative physical theories have been devised; and insofar as they are internally consistent and are confirmed by experience, they, too, are conventionally valid.

If everything that we believe to exist depends upon mental and verbal designation, it follows that different cultures and even different individuals may dwell in diverse conventional realities. First of all, the experiential evidence that they choose to interpret may be different; and secondly, the manner in which they choose to interpret it may also be different. Nevertheless, when we draw back from such analysis, even if we find it persuasive, we look out upon a world that seems to exist entirely in its own right, independent of conceptual imputation. Although the world lacks intrinsic existence, it certainly <u>appears</u> to exist in its own nature. There is, thus, an incongruity between the mode of existence of phenomena and their mode of appearance. Things appear to have a more concrete, or substantial, existence than they actually have; and <u>in this sense</u> they may be likened to illusions, reflections and mirages.

Such a statement is regarded by some physicists as being incompatible with Western science.[9] However, if physics, from the time of Galileo onward, has taught us anything about the physical world, it has told us that sensory experience and the "common sense" based upon it is not an infallible guide to the nature of physical reality. Sensory experience clearly demonstrates that the sun revolves around the earth, but Galileo challenged such appearances with the heliocentric theory. The infallibility of sensory experience has been most dramatically challenged by twentieth-century physics, from relativity theory to quantum theory. The innumerable instances of this hardly need to be recounted here. A full appreciation of this fact may lead us to agree with biologist J.B.S. Haldane when he said:

> Now my own suspicion is that the universe is not only queerer than we suppose, but queerer than we can suppose.[10]

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[9] See Stephen Hawking's Universe: An Introduction to the Most Remarkable Scientist of Our Time, John Boslough (William Morrow & Co., Inc., N.Y., 1985) p. 127.

[10] Quoted in "Experiment and the nature of quantum reality," T. Mike Corwin and Dale Wachowiak, The Physics Teacher, Oct., 1984, p. 429.

CHAPTER TWENTY-SIX:

A CENTRIST VIEW OF PHYSICS

From the perspective of the centrist view we may readdress the question: What knowledge does physics yield concerning the nature of the universe? As we have noted previously, the program of physics has been to make experiment and observation, together with mathematical analysis, the means for understanding physical reality that lies behind appearances. This Cartesian approach assumes that Nature exists independently of the mind and that it bears little resemblance to the world that we perceive directly. Experience is thus used as a test to confirm or refute physical theories about the world as it exists in a way that transcends experience. Qualms about this weird juxtaposition of empiricism and transcendentalism are to be relieved with the conviction that the transcendental world of physics is of a mathematical nature; and it is by such analysis that its reality can be grasped.

On this metaphysical basis generations of physicists have devised a myriad of theories, based on mathematics, proposing the existence of such noumenal entities as gravity, energy, ether, electromagnetic fields, spacetime and quarks. For such theories to be deemed "scientific," they must yield predictions that can be tested empirically. The closely related assumption is that a theory is "confirmed" when its predictions are born out empirically. When physics is taught in the classroom and experiments are done in the laboratory, this assumption is generally taken for granted without further reflection: If one's data correspond to the predicted results, the theory in question is deemed true of reality.

Experienced physicists are well aware, in their more reflective moments, that this is a naive and misleading assumption. The fact that multiple, conceptually incompatible theories may equally account for the same phenomena was known by the ancient Greeks; it was recognized by the Church at the time of Galileo; it was acknowledged during the late nineteenth century, at the peak of classical physics; and it is no secret in contemporary physics. When presented with this fact, a realist will most likely respond that verification of a theory on the basis of its ability to predict phenomena does not confirm that it is true of reality; but by a gradual process of elimination, false theories are empirically eliminated, thereby yielding an ever closer approximation of truth.

As demonstrated earlier, such a view is above all an expression of faith that is based not on historical evidence or present scientific grounds, but on hope. The centrist view responds that such faith is misguided and such hope is in vain. Empirical science has never been successful in yielding knowledge of a transcendent world independent of experience. Its assertions of the existence of noumena lurking behind the veil of appearances are verified neither by direct experience nor inference.

The centrist view does not make the ridiculous assertion that physics therefore knows nothing at all. It has provided a vast body theoretically related knowledge about phenomena--events observed in the laboratory and so on. In this sense there is no doubt that science has progressed from Aristotle to Galileo to the present. Such knowledge has been enormously useful in furthering technology, including the construction of instruments that further its own progress. But what shall we make of scientists' claims of knowledge concerning noumenal events independent of observation? The centrist view neither acknowledges their real existence--as does realism--nor does it deny their existence--as does the thoroughgoing instrumentalism. Rather, it places them on trial, awaiting experiential verification of their existence.

We do not now know whether the noumena of modern physical theories exist or not. Thus, we may conceptually "hold them in custody," in the ontological limbo of being neither existent nor non-existent. Or, if we find our minds overcrowded with these theoretical suspects, we may conceptually release them as non-existent until experiential verification to the contrary is produced. It should hardly need to be said that "experiential verification" does not occur when a theory that incorporates such noumena yields an empirically confirmed prediction. Such circumstantial evidence neither confirms nor denies the existence of the noumena proposed in physics, so it must be thrown out of court. Regardless of the quantity of such evidence, it does not justify the conviction that the noumenon in question exists.

What then does constitute experiential verification? Such verification can be produced by only one type of instrument, and that is cognition. What types of cognition do we have available? In Western civilization it is commonly asserted that we can perceive the physical world with our five senses, and the mind allows us to think about such perceptions. But none of these modes of cognition hold much promise in terms of verifying the existence of a noumenon such as the zero-point energy of the vacuum. If these are our only cognitive resources, the trial to judge the existence of the energy of the vacuum must be closed as soon as it opens: The verdict is left at "no verdict," with no clues for furthering the investigation.

To our good fortune, our civilization is not the only one on this planet; and just as Western civilization has its own unique discoveries, so do others have theirs. The centrist view that has been presented in this and the preceding chapters is a contemporary application of the Centrist View of Buddhism, known in Sanskrit as "Madhyamika." This Centrist View traces back 2500 years to the teachings of the historical Buddha. It was studied and practiced in India for some 1500 years; and for the past millennium it has flourished in the Buddhist cultures of central Asia, where it has widely been regarded as the pinnacle of Buddhist philosophy.

The Centrist View of Buddhism is primarily concerned with questions of ontology--the essential mode of existence of things. However, in order to investigate the fundamental nature of the human body and mind, for example, one must first clearly ascertain their phenomenal characteristics. Buddhist contemplative science has, thus, long been concerned with the phenomenological study of physical and cognitive events. Although the five senses and the mind's capacity for thinking are certainly used in this pursuit, this science has developed other mental faculties that are crucial for such investigation. Methods, some of them predating Buddhism in India, have been discovered for profoundly stabilizing and clarifying mental awareness.[1]

Upon accomplishing high degrees of mental refinement, it is possible to direct one's heightened awareness not only

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[1]For an extremely informative and authoritative account of many of the most fundamental practices in such mental training see Paravahera Vajirañāṇa Mahāthera's Buddhist Meditation in Theory and Practice (Buddhist Missionary Society, Jalan Berhala, Kuala Lumpur 09-06, Malaysia, 1975).

to gross physical and cognitive events here and now, but to extremely subtle events and others that are distant in time and space. The great fifth-century Indian Buddhist sage Buddhaghosa lists five types of heightened awareness, some of which can be of great use in the exploration of nature.[2] He also describes various mental powers of "psychic technology," which must be of interest to people seeking a thorough understanding of the natural laws of the universe (including both physical and cognitive laws).[3] On the basis of the Buddha's teachings, Buddhaghosa also explains in detail how each of these types of heightened awareness and mental powers are achieved.

Many of these mental abilities are not unique to Buddhist contemplative science. The great Indian Hindu contemplative Patanjali (possibly a contemporary of Buddhaghosa) also presented methods for developing a wide range of supernormal powers.[4] These techniques, which Patanjali mostly compiled from the discoveries of earlier contemplatives, are different from those set forth by Buddhaghosa; but many of the results appear to be

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[2] The Path of Purification, Bhadantacariya Buddhaghosa, trans. Bhikkhu Ñāṇamoli (Buddhist Publication Society, Kandy, Sri Lanka, 1979) Ch. XIII.

[3] ibid. Ch. XII.

[4] cf. Swāmi Hariharānanda Āraṇya's Yoga Philosophy of Patañjali, trans. P. N. Mukerji (State Univ. of New York Press, Albany, N.Y. 1983) Book III.

essentially the same. There is certainly widespread agreement among these contemplative traditions as to the immense potential of human consciousness, both as an instrument for investigating reality and as an instrument of power.

The accomplishment of such abilities, however, does not necessarily imply that one who wields them is an infallible judge of reality. In Western society, if a scientific theory makes a prediction that is verified by experience, naive devotees of science are wont to believe that the entire theory is true of reality. Similarly, in traditional Indian society, if a contemplative makes accurate predictions about the future, naive devotees are prone to regard that person as an infallible source of wisdom. Technological wonders also may, at first glance, suggest a profound understanding of nature, just as displays of psychic powers may overawe their beholders. In both cases the ability to manipulate phenomena does not necessarily imply an understanding of the more subtle processes involved.

Different contemplative traditions do proclaim varying theories concerning topics ranging from human physiology and psychology to cosmology. However, in many areas there appears to be conformity of experience.[5] To begin to

[5] We should also note that not all Indian philosophies have a contemplative basis. The most outstanding example of a non-contemplative view is that of the Charvaka school, which arose

understand the differences, we may recall Heisenberg's statement that "what we observe is not nature in itself but nature exposed to our method of questioning."[6] Hindu and Buddhist contemplatives question nature in somewhat different ways, so it is to be expected that their observations will vary to some extent. The contemplative mode of questioning is strikingly different from that of technological science, and the types of understanding gained from the two approaches differ correspondingly. The Centrist view acknowledges that contrary theories do not necessarily invalidate one another; they may be complementary.

The notion that Eastern contemplative science may complement Western technological science must strike many people as bizarre. Physicist Stephen Hawking is an outspoken critic of any such meeting of Eastern and Western knowledge. In an interview with Professor of Philosophy

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around 600 BC. This philosophy is a fairly thoroughgoing positivism which admits the existence of no universal laws of nature, causal or otherwise. Every event is chance, and only matter is real. It refutes the existence of God and any objective ethical laws and declares that any action done for the sake of pleasure is justified. Consciousness is regarded as nothing more than an emergent quality of certain configurations of parts of the body, and it vanishes at death. For obvious reasons, the Charvaka philosophy was widely regarded by both Hindu and Buddhist contemplative schools as theoretically unintelligent and ethically perverse.

[6] Physics and Philosophy: The Revolution in Modern Science, W. Heisenberg (Harper & Row, Pub., N.Y., 1962) p. 58.

Renée Weber he explains his dislike of what he terms "mysticism" on the grounds that (1) it clouds issues with obscurity and (2) it does not provide good theories in Karl Popper's sense of making definite predictions that can be falsified.[7]

In responding to this objection by a great scientist, we must first acknowledge that much of what passes for "mysticism" is to Eastern contemplative knowledge what scientism is to scientific knowledge. There is a large market in the West for both phony mysticism and phony science, and both are equally seductive to the dilettante. It requires informed discrimination to glean authentic information from the popular literature; and mastery of the writings of professional contemplatives and professional scientists requires years of intensive training. It is most unfortunate to discard either body of knowledge as worthless simply because one has not bothered to separate the grain from the chaff.

Much of the professional literature of Buddhist contemplative science is extraordinarily exacting, lucid and logically coherent. This should come as no surprise, for intellectual training in the Buddhist monastic colleges and universities of such countries as Sri Lanka and Tibet is

[7] Dialogues with Scientists and Sages, Renée Weber (Routledge & Kegan Paul, N.Y., 1986) p. 210.

long and demanding.[8] Hawking's comment that people turn to mysticism because they find theoretical physics and mathematics too hard may be true of a few Western dilettantes. But such people would find that serious study and practice of Buddhist contemplative science is at least as challenging as the study of theoretical and experimental physics.

Does Buddhist contemplative science produce theories that make definite predictions that can be falsified? Without a trace of doubt, the answer is definitely affirmative. However, the primary focus of interest of Buddhist contemplatives has traditionally been quite different than that of physicists. For former have been pragmatically concerned chiefly with the nature and problems of human existence and the untapped resources of consciousness. Their writings abound with precise explanations of techniques for refining awareness, balancing the mind and unleashing its latent powers. Such documents give definite predictions concerning the types of experiences that will arise when those methods have been properly executed; and they are been experientially confirmed by many generations of contemplatives.

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[8] For an account of the twenty-four year training of a monk in one of the major monastic universities of Tibet see The Life and Teachings of Geshé Rabten trans. and ed. B. Alan Wallace (George Allen & Unwin, London, 1980). It should be emphasized that this intellectually tremendously demanding course of training places heavy emphasis on logic and clarity of thought.

Such research has revealed a number of cognitive laws of the universe that have been discovered and verified experientially. Buddhist contemplatives have been far less concerned with physical laws concerning such things as gravity and electricity; so their writings contain little or no references to purely physical predictions. This does not mean that the forms of heightened awareness that can be cultivated using Buddhist methods cannot be used to explore subtle physical events and the laws that govern them. It simply means that such contemplatives have found other fields of research more compelling.

One who is accustomed to the world view of modern Western science will likely be very skeptical of the specific Buddhist and Hindu claims of heightened awareness and other mental powers unbelievable. This is a natural response, for such potentials of the human mind are virtually unknown in Western civilization. However, productive skepticism does more than complacently rest in the conclusion that such claims must be unfounded. They must be put to the test of experience. If one travels to India and patiently seeks out experienced contemplatives, one can find those who possess extraordinary mental powers; but one will likely first meet with a number of charlatans.

A greater challenge is to test such claims by engaging oneself in Buddhist or Hindu methods of mental training and testing experientially the predicted results. Even modest efforts in this field, when performed correctly under competent guidance, can yield significant results. The task of becoming a professional contemplative and profoundly transforming the mind is naturally far more demanding and time-consuming.

Inevitably, some skeptics will complacently nurture their disbelief in knowledge gained using unfamiliar methods, without taking any steps experientially to settle the matter for themselves. Galileo encountered such people when he proclaimed his astronomical discoveries using a primitive telescope. His findings contradicted Aristotelian physics, which was widely accepted by the intellectuals of his day; and some of his opponents reportedly refused to look for themselves through his telescope at such things as lunar craters. Such things simply could not exist, for the prevailing view of the heavens disallowed their presence. Even if they were visible through the telescope, these adversaries were already convinced that such apparitions were due only to distortions in the lenses. They were apparently not sufficiently motivated to study optics and the technology of grinding lenses to see whether their assumptions were substantiated. Those critics thereby removed themselves from participation in the Scientific Revolution, and they were to see their world view steadily eroded by the science that they chose to ignore.

Similar skepticism has been expressed with regard to contemplative discoveries when they cannot be verified by other means. The most frequent charge is that events observed as a result of contemplative training are creations of the observer's imagination. In fact, many claims of supernatural visions by self-proclaimed mystics can be discarded as fantasies--such dilettantes and charlatans abound in the East and the West. But the prevalence of frauds does not refute the existence of others who have gained profound contemplative experience of various facets of reality.

In Buddhist mental training great emphasis is placed from the outset on distinguishing between the fantasizing mind and verifying cognition. Indeed, the tendency of the human mind to assume the existence of things that are in fact non-entities is considered to lie at the root of a broad range of unnecessary conflicts and miseries. The most basic expression of this mental distortion is the reification of oneself as an intrinsically existent personal identity. Having reified oneself, it is inevitable that one reifies others in the same way, and this sets up absolute demarcations between "self" and "other." One naturally also reifies one's natural environment as intrinsically existent, and therefore as absolutely "other."

When such a view is put into action, the program is set for establishing one's own well-being as opposed to, and possibly at the expense of, that of other people. And one's environment, seen--like other people--as unrelated to oneself, is manipulated toward one's own ends. Such reification encourages the view that one can ravage other sentient beings and one's environment with impunity: People are to be exploited, and Nature is to be conquered.

The Centrist view acknowledges the obvious truth that one person is different from another and that they are different from their inanimate environment. But such distinctions are of a conventional, not an absolute nature. This does not mean that such demarcations are arbitrary. Rather, the Centrist view asserts that they exist in dependence upon conceptual designation. Every sentient being and every inanimate object thus exists as a dependently related event.

Ignorance of this essential truth gives rise to other mental distortions as well. In dependence upon the sense of an absolute self as opposed to absolute others, there arises selfish desire for objects (sentient and otherwise) that are regarded as being conducive to one's own well-being. Similarly, there arises hostility toward objects that appear to threaten one's well-being and that stand in the way of the fulfillment of one's desires. When people who are subject to such mental afflictions interact with one another, conflict, frustration and pain are inevitable.

Western science is based on the reification of the objective world. It initially adopted the Cartesian decision to reify subjective consciousness and to displace it from the reified world of nature. Over the ensuing centuries, mind has fallen to the epiphenomenal status of a function of the brain; and it is assumed to have originated from a chance configuration of unconscious matter and energy. Physical science has, in the meantime, discovered many of the laws of nature; and some physicists, including Stephen Hawking, speculate that within twenty years, a complete unified theory may well be established. Hawking is reasonably confident that Western science knows the history of the universe up to one second after the Big Bang. That first second, he acknowledges, is still something of a mystery; but as soon as it is understood with certainty, "we'd really know everything...We'd have solved all the problems and it would be rather dull."[9]

It is hardly a secret that some of the most prominent physicists at the end of the nineteenth century were equally confident that knowledge of the universe was virtually complete.

That, of course, was just a few years before the modern revolution in physics, entailing the emergence of relativity theory and quantum mechanics. Can a complete understanding of the universe be gained in principle, if not in detail,

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[9] Dialogues with Scientists and Sages, p. 208.

while ignoring the role of consciousness? The Centrist view clearly denies this possibility. The distinction between the subjective mind and the objective world is a conventional one, existing in dependence upon conceptual designation. Thus, if physical events do not exist independently of cognitive events, understanding of the former can hardly be complete, even in principle, without accounting for the latter.

Unlike education in physics, Buddhist contemplative training entails a strong emphasis on moral responsibility. Before attempting to gain profound states of heightened awareness or extraordinary mental powers, the aspirant must attenuate his or her own mental distortions such as selfish desire and hostility. As one ascends to increasingly advanced states of contemplative awareness, one must complement such progress with the cultivation of such virtues as lovingkindness, generosity and patience. Insofar as the powers that one gains are guided by wisdom and motivated by compassion, they are of benefit to oneself and others. It is for such balanced development that one strives in Buddhist mental training.

The preceding discussion does not suggest that Western science be discarded in favor of Eastern contemplative science. The former has yielded benefits that the latter has not. Nor should the two be set in competition with each other in a misguided attempt to determine which is "best."

Each has its unique advantages and drawbacks, and is a civilization's loss to discard either. At present we are in a position to draw from the wisdom of the East and the West to create a civilization of planet Earth. The problems that face humankind are severe, and any lesser solution may be insufficient.

CHAPTER TWENTY-SEVEN:

EXPERIENCING A CENTRIST VIEW

The centrist view sketched in the preceding chapters declares that everything that exists lacks an intrinsic nature, or identity. How then do things exist? All entities are viewed as dependently related events, and none bear a self-defining, independent existence. Such events are dependent, for their very existence, upon the power of the mind and convention that designates them; and even the mind itself bears only such a conventional identity.

When a subatomic particle, for instance, is first discovered, it is conceptually designated as existing with a certain set of attributes. If that designation is consistent within the theory in which it is incorporated and is verified by experience, it is valid. If, after some years, the accepted subatomic theory changes and that particle no longer has a place in contemporary theory, it may from that vantage point not be attributed with existence. Thus, if we declare that a certain subatomic entity exists, we must at least implicitly identify the conventional system in which it plays a part. The conventional realities of two simultaneous, diverse cultures may be significantly different; and this is also true of the realities of a single culture over a period of centuries, and even of a single individual who experiences a fundamental change in world view.

Composite entities are also viewed as dependently related events in that they occur in dependence upon causes and conditions. Moreover, all things are dependently related events in the sense that they depend upon their own components or attributes. They are not identical with their properties, nor are they independent of them; rather, they depend upon them for their existence.

The Centrist view may be regarded chiefly as an ontological theory; and, as a metaphysical view, we might assume that its truth or falsity is beyond the reach of experience. As mentioned previously, the treatment of this view in the preceding pages has been in fact a brief introduction to the <u>Madhyamika</u>, or Centrist View, of Buddhist philosophy. In its native context, it is presented as a system of intellectual inquiry as a means for experiencing reality in profoundly different way.

This approach of employing philosophical theory as a means of refining and deepening one's personal experience of reality is not alien to Western civilization. The Greek word for theory (<u>theoria</u>) meant "contemplation"; and it is the term used in Aristotle's psychology to designate the moment of fully conscious participation, in which the soul's potential knowledge becomes manifest. Only then can the individual at last claim to be "awake."[1]

Western civilization has unfortunately allowed this dimension of "theory" to atrophy in the context of modern scientific and philosophical systems of thought. Insofar as its religions have divorced themselves from their contemplative, or mystical, wellsprings, religious doctrine, too, often is not recognized as a means of profoundly deepening one's experience of reality.

The assumption that intellectual insight must remain divorced from personal experience is certainly challenged in classical Greek thought. Plato recognized three levels of knowledge. The first of these is derived from simple observation, such as the observation of the movements of the stars, sun, moon and planets. The second level deals in geometry, by means of which one devises orderly, mathematical accounts for the apparently arbitrary movements of the planets. This level of knowledge includes the science of astronomy. The third level entails an unobscured participation in the divine Mind, or Word; and such knowledge cannot be gained without profoundly transforming one's own mode of experience, or awareness. It is not accessible to logic alone. For Aristotle this third level of true knowledge was not of a transcendent, "mystical"

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[1] Saving the Appearances: A Study in Idolatry, O. Barfield (Faber & Faber, London, 1957) p. 49.

nature, but rather an experience of "ordinary" reality unobscured by the veils of bewildering mutability.

Contemporary Western civilization has apparently forgotten how to cultivate this third level of personally transformative knowledge, as it has forgotten the deeper meaning of "theory." The direct means for deepening and raising our level of awareness calls for a qualitative, contemplative science. Such a science would yield insight not only into the nature of the mind but the physical world as well. At present we lack such a science in the West, but it would be rash to conclude that it has been developed nowhere else.

Western civilization has created philosophy as a discipline separate from empirical science, and it has artificially divorced both from religion. In contrast to philosophy and religion, science has progressed largely due to the fact that it has devised means of empirically testing its theories. In so doing, it has brought us much conceptual understanding of, and power over, the physical world. But it has shed little light on the nature of consciousness, as one of the fundamental constituents of the universe together with space, matter and energy. Nor has it shown us how to transform our way of directly experiencing reality in accord with its deepening insights.

Buddhist civilization of classical India, East Asia and Tibet did not develop the triad of science, philosophy and religion as autonomous disciplines. Each of these avenues of understanding were indeed cultivated, but they were traditionally regarded as fundamentally interrelated. In these cultures a qualitative, contemplative science was created and developed over two and a half millennia. Its fundamental aim is to transform personal experience such that one gains direct insight into reality. This goal has been realized not just once by the historical Buddha, but thousands of times by later contemplatives. Indeed, the practical methods that it offers are still accessible and are still effective.

The empirical methods of "contemplative research" presented as part of the Centrist View in Buddhism lead one to a direct realization of the nature of phenomena as dependently related events. This approach does not entail quantitative analysis or theory couched in mathematical terms; but it does, nevertheless, address many of the fundamental ontological issues that are being investigated in the context of the foundations of modern physics. For this reason there may be meaningful dialogue between scientists concerned with such questions and those who have gained conceptual and experiential insight into the Centrist View.

Among the contemplative traditions of classical Indian culture, diverse, mutually incompatible theories are promoted concerning the fundamental nature of reality. This suggests that there are many levels of insight that arise from contemplative practice; and the manner in which those insights are interpreted may vary greatly. In some cases, differing techniques may lead to the same realization, and it may also happen that the same realization may be interpreted in different ways. As one engages in contemplative research, it is very possible for one to regard an experience as "ultimate," feeling that one has realized the essential nature of reality; whereas in fact there is far deeper insight to be gained.

Even among Buddhist treatises several mutually incompatible ontological theories are taught. The Buddhism of central Asia, (i.e. Tibet and other countries strongly influenced by Tibetan Buddhism) utilizes these theories in monastic training in a sequential way. In many Tibetan monastic universities, students are first introduced to a form of dualistic realism in which both cognitive and physical events are attributed with real, intrinsic existence.[2] Strong emphasis is placed on logical analysis

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[2]The Buddhist philosophies known as Vaibhashika and Sautrantika are included in this category. A type of contemplative practice that forms an excellent complement to the theoretical study of these two schools is the Four Applications of Mindfulness. In such training one experientially investigates the phenomenological nature of the body, feelings, the mind and other mental and physical events. On that basis on proceeds to examine their fundamental mode of existence as well as the nature of the self. This practice is discussed in Soma Thera's <u>The Way of Mindfulness</u> (Buddhist Publication Society, Kandy, Sri Lanka, 1975).

and on the study of the causal interrelations among such phenomena. Following this phase of the training, students are introduced to a form of Buddhist idealism[3], which challenges the existence of a physical world independent of consciousness, while asserting the absolute, intrinsic existence of the mind. As their understanding is refined by such training, they enter the study of the Centrist View, which asserts the existence of cognitive and physical events, while denying the intrinsic existence of both.

All of these ontological views are traced back to the Buddha's own teachings. Each one is used to dispel certain levels of ignorance, especially involving reification. Thus, the student ideally engages in one of these philosophical systems both theoretically and contemplatively until the insights that it was designed to yield have been gained. One then naturally proceeds to a deeper view. The most profound ontological theory is considered to be the Centrist view; and when one's mind is freed from all obscuring reification, the conceptual apparatus of this system, too, is left behind. It was designed as an instrument for gaining direct experience of reality, and when that is achieved, it has served its purpose. In this sense, Buddhist philosophy is above all pragmatic.

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[3]This philosophy is known as Vijñanavada.

Buddhist contemplative science contains hundreds of methods for investigating not only the ultimate nature of phenomena but the conventional, or relative, nature of physical, mental and other types of entities. Even in terms of exploring the ultimate mode of existence of phenomena there are a wide variety of techniques. Here we shall briefly look into just one of these methods.

As mentioned previously, the Centrist View regards the emptiness of an intrinsic nature to be the ultimate, or essential, mode of existence of phenomena. The truth of this is established first of all through observation, study and logical analysis.[4] When conceptual insight is gained in this way, one proceeds to seek experiential realization by means of meditation. One could begin by empirically exploring the fundamental mode of existence of space, matter, consciousness or any other entity; but the preferred approach in Buddhist practice is to begin exploring one's own essential nature.

While devoid of an independent identity, the self does exist as a dependently related event; and it exists in dependence upon mental imputation. Similar investigation is brought to bear on the mind, the body and other entities, and the conclusion is the same: All of these are empty of

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[4]For a detailed description of the intellectual training involved in exploring the Centrist View of Madhyamika in the monastic universities of Tibet see <u>The Life and Teaching of Geshé Rabten</u>.

an independent, intrinsic nature; but they do exist as dependently related events. As one gains deeper experiential insight, it becomes apparent that for the very reason that entities do exist as dependently related events, they cannot possibly bear intrinsic identities. Because they are empty of a self-defining nature, they are able to enter into dependent relationships with other phenomena.

The meditations on emptiness employ rational thought, but they result in a penetrating awareness that transcends concept and verbal description. Initial insight into the nature of emptiness is mixed with the idea of emptiness, but as experience deepens, a non-conceptual, direct realization of this truth is experienced. In that state, one no longer has any sense of a subject/object dichotomy, nor any differentiation between "this" as opposed to "that." When first abiding in such a realization, one has no awareness of conventional reality at all. As one proceeds to "full awakening," the challenge is to integrate this profound insight with one's experience of relative truth, in all its diversity.

Such meditative practice is exceedingly subtle. If the mind is not previously refined by means of meditation, one may still gain a glimpse of this ultimate nature, but its impact upon one's consciousness will be very limited. Thus, in traditional Buddhist practice, such "insight" training is preceded by methods for stabilizing and refining one's awareness. In this regard, the minimum prerequisite for fully effective insight training is the attainment of "meditative quiescence." With this accomplishment the mind can be focussed single-pointedly, without distraction and without effort, for roughly four hours continuously, with vivid clarity.

Such a refinement of awareness obviously entails a major transformation of consciousness, and this is not easily brought about. In general it can be achieved only by months of continuous mental training usually pursued in solitude, free from the distractions of ordinary daily life. If one engages in such practice correctly, with skillful guidance, it results in an unprecedented state of mental and physical buoyancy and well-being. If one enters such intense training prematurely, it can lead to serious mental and/or physical imbalance.

Because of this danger, such an endeavor is properly preceded by a thorough training in generally refining the quality of one's awareness in active daily life. A mind that is frequently subject to hostility, sensual craving, lethargy, confusion and semi-conscious, conceptual rambling is unfit for serious training in meditative quiescence. Thus, a wide variety of methods are employed on a day-to-day basis for subduing these mental distortions. In the process, one's general emotional and mental condition improves, and one's physical health may well also be enhanced.

In Buddhist contemplative science the initial, fundamental concern is not with the ontological status of atoms, but with the human condition of suffering and discontent. Why are we subject to unhappiness, so much of it apparently unnecessary and fruitless? Certainly external conditions can be found that lead to physical and mental pain, and it is appropriate to seek external means of dealing with them. Medicine, improved agricultural techniques, modern technology and environmental constraints on the misuse of technology can all be effective means in this regard. But despite the awesome powers that modern science has brought to us, such external measures have not proven effective in bringing about inner contentment or well-being.

Buddhist contemplative science turns then to the inner sources of conflict, strife and misery. Certain types of physical, verbal and mental activity are recognized as leading to suffering for oneself and others, and these are regarded as "unwholesome." The roots of such behavior have been empirically identified to be distortions of the mind such as hostility, craving and confusion. Buddhist practice therefore focusses, from the outset, on diminishing the power of such distortions and their resultant unwholesome behavior. The fundamental mental affliction is confusion, and this refers specifically to the tendency of reifying oneself, others and the world at large. Such confusion conceives of oneself and all other entities as bearing intrinsic, absolute existence; and this mental distortion lies at the root of all other mental afflictions.

The individual does not exist as an isolated, independent entity, intrinsically cut off from other sentient beings and the rest of the universe. Rather, each person exists as a dependently related event: Neither our existence, nor our degree of well-being is independent from the rest of our environment. Recognizing this, a Buddhist contemplative who aspires for full spiritual awakening strives not only for his/her individual enlightenment, but for the awakening of all sentient beings.

With such a motivation one refines the quality of one's standard of living (referring to the quality of one's life, not one's material possessions). By implementing methods of diminishing mental distortions and unwholesome behavior in active daily life, one approaches the degree of inner purity that is required for effective training in meditative quiescence. This is the next major step of contemplative practice, and upon mastering it, one properly moves on to insight training focussed on gaining realization of ultimate truth--the emptiness of intrinsic existence of all phenomena.

The foregoing introduction to the practice of Buddhist contemplative science has been very general. The precise tenets of the Buddhist Centrist View and the specific methods for experiencing that view are best learned by looking to the classic literature of Buddhism. Such treatises were generally authored with the understanding that they would be orally elucidated by successive generations of teachers who had gained theoretical and experiential insight into their contents. For this reason the present work concerned with demystifying the foundations of physics is followed by a translation of a chapter of one of the greatest classics of Buddhist contemplative science. Authored in the eighth century of the Christian era by an Indian Buddhist sage, it is presented here with the translation of an oral commentary by the present Dalai Lama. He is acknowledged as an eminent teacher of this subject, and he is a link in a continuous succession of teachers and students tracing back to the author of the text, Shantideva.

W O R D S O F E M P T I N E S S

A CENTRIST VIEW OF SCIENCE AND REALITY

B. Alan Wallace

Submitted to the Department of Independent Studies of Amherst College in partial fulfillment of the requirements for the degree of Bachelor of Arts with Honors.

Faculty Advisor:

Arthur G. Zajonc, Assoc. Prof. of Physics

Readers:

Arthur G. Zajonc, Assoc. Prof. of Physics

Robert A. Thurman, Prof. of Religion

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T A B L E   O F   C O N T E N T S

B O O K: II

T R A N S C E N D E N T   W I S D O M

THE NINTH CHAPTER OF SHANTIDEVA'S

GUIDE TO THE BODHISATTVA WAY OF LIFE

With commentary by

H. H. the Dalai Lama, Tenzin Gyatso

PREFACE:

THE PLACE OF WISDOM IN SPIRITUAL PRACTICE

1. This entire preparation the Sage taught for the sake of wisdom. Thus, one wishing to bring an end to suffering should develop wisdom.

"This entire preparation" refers to the first five transcendent practices of generosity and so on[1]; or it may refer to meditative absorption.[2] All of these were taught by Buddha Shakyamuni in order to cultivate ultimate wisdom. In order for the realization of emptiness to arise in the mind, it is not necessary for one to engage in the other transcendent practices as well. According to the view of the author of this text and of Chandrakirti and Buddhapalita, Listeners[3] and Solitary Sages[4] overcome spiritual hindrances by their respective Paths of Seeing and

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[1]The first five transcendent practices are generosity, moral discipline, patience, enthusiasm and meditative absorption. The sixth is transcendent wisdom.

[2]Skt.: dhyāna, Tib.: bsam brten. Throughout the text, when two terms are cited in a footnote, the first, as in this case, will be in Sanskrit and the second in Tibetan. If only one term is cited, it will be in Tibetan.

[3]śrāvaka, nyan thos

[4]pratyekabuddha, rang rgyal

of Meditation by means of the view of emptiness.[5] Thus, the practice of transcendent generosity and so on is not necessary for the cultivation of that view; nor is it necessary for eliminating the afflictive obscurations[6].

What is the nature of wisdom? The view of emptiness entailing the integration of meditative quiescence[7] and insight[8] acts as the antidote for cognitive obscurations[9];

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[5] For a concise explanation of the Listeners and Solitary Sages see H.H. the Dalai Lama's Opening the Eye of New Awareness (Wisdom Pub., London, 1985) pp. 85-90. Listeners, Solitary Sages and Bodhisattvas attain their respective degrees of spiritual awakening by developing along their five respective paths. These are the: (1) Path of Accumulation, (2) Path of Preparation, (3) Path of Seeing, (4) Path of Meditation and (5) Path of No Training. A person suited for the Listeners' Vehicle, for example, attains the Listener's Path of Accumulation upon achieving effortless, pure renunciation. The Path of Preparation is reached upon completing the Path of Accumulation and experiencing integrated meditative quiescence and insight into the nature of emptiness. Such realization is mixed with the general idea of emptiness. The Path of Seeing is reached upon gaining direct realization of emptiness free of the veil of even the most subtle conceptualization. The Path of Meditation entails repeated insight into ultimate truth, thereby dispelling all mental distortions. The Listeners' Path of No Training is reached when that process of mental purification is complete: The mind is now completely free of mental distortions together with the "seeds" for their arisal. The Five Paths of Solitary Sages and Bodhisattvas differ from those of Listeners, and they culminate in higher degrees of awakening. For further explanation of those three sets of the Five Paths see Geshey Ngawang Dhargyey's Tibetan Tradition of Mental Development (Library of Tibetan Works and Archives, Dharmsala, India, 1974) pp. 183-201.

[6] kleśāvaraṇa, nyon mongs pa'i sgrib pa. These obscurations include primarily confusion, craving and hostility.

[7] śamatha, zhi gnas

[8] vipaśyanā, lhag mthong

and with that view one experiences the subtle mode of existence of entities.[10] It is a wisdom that arises from meditation. But such wisdom alone is insufficient for overcoming those obscurations. Without being combined with a great store of virtue, that wisdom cannot be an antidote for the cognitive obscurations.[11] The major obstacles to the attainment of full spiritual awakening are the cognitive obscurations. Ultimate wisdom is their direct antidote. To cultivate that, this series of practices must be followed, thereby accumulating great virtue. Thus it is said: "This entire preparation the Sage taught for the sake of wisdom." Thus, one who wishes to bring an end to the suffering of oneself and others should develop such wisdom.

There are no teachings of the Buddha that are not means

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[9] jñeyāvaraṇa, shes bya'i sgrib pa. These include, for example, the instincts of mental afflictions and the appearance of things as being truly existent.

[10] For an explanation of meditative quiescence and insight based on the scriptures of Theravada Buddhism see Amadeo Solé-Leris's Tranquility and Insight (Shambhala Pub., Inc., Boston, 1986). A Centrist explanation of these two facets of Buddhist practice is given in Jeffrey Hopkin's Meditation on Emptiness (Wisdom Pub., London, 1983) pp. 67-110.

[11] By engaging in wholesome activities of the body, speech and mind one accumulates a "store of virtue." Such behavior places beneficial imprints upon the mind, and these are an indispensible aid to spiritual awakening. Buddhist practice continually emphasizes the balance between the cultivation of wisdom and involvement in altruistic activity motivated by compassion. Further reference to the two types of obscurations is given in Meditation on Emptiness, p. 300.

for living creatures to attain prosperity[12] and true felicity[13]. True felicity refers to liberation and omniscience, and to attain either, the view of emptiness is necessary. To dispel either the afflictive obscurations or the cognitive obscurations one must cultivate the view of emptiness. Thus, the entire "method" element of the Buddha's teachings, not only transcendent generosity and so on, was given for the sake of cultivating wisdom. The Listeners and Solitary Sages must also develop wisdom with the aid of the method element; wisdom cannot be gained without it. Here the term "method" does not refer to the spirit of awakening[14] or to taking upon oneself the responsibility for the welfare of others. There are many virtues such as concentration that are cultivated with the motivation of a aspiring to gain one's own release from the cycle of rebirth[15]. In this way, by following the Three

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[12] abhyudaya, mngon mtho. This refers to birth in the fortunate realms of existence as a human being, a demigod or a god.

[13] niḥśreyasa, nges legs

[14] bodhicitta, byang chub sems. This spirit of awakening entails the aspiration to achieve the full spiritual awakening of a Buddha in order to be of benefit to all sentient beings. Further explanation can be found in Jeffrey Hopkin's <u>The Tantric Distinction</u> (Wisdom Pub., London, 1984) pp. 58-74.

[15] For an explanation of the Buddhist concept of cyclic existence see <u>Meditative States in Tibetan Buddhism</u> by Lati Rinbochay, Denma Lochö Rinbochay, Leah Zahler and Jeffrey Hopkins (Wisdom Pub., London, 1983) pp. 23-47. Liberation from this cyclic existence is called "Nirvana."

Trainings[16], mental afflictions[17] are eliminated. All those methods were taught for the sake of liberation.

[16]The Three Trainings are in moral discipline, concentration and wisdom. See Opening the Eye of New Awareness, pp. 53-84.

[17]kleśa, nyon mongs. I have translated this important term both as mental distortion and mental affliction, so they are used synomymously. The first translation brings out the fact that kleśas distort our experience of reality and thereby lead us into suffering. The second translation emphasizes that they are maladies of the mind, suggesting both that they are a source of pain and that the afflicted mind can be healed.

PART ONE:

THE METHODS NEEDED FOR CULTIVATING WISDOM

CHAPTER ONE:

INTRODUCTION TO THE TWO TRUTHS THAT COMPRISE REALITY

The Classification of the Two Truths

2. The twofold truth is considered to be conventional and ultimate. [Ultimate] reality is not an object of the intellect; the intellect is called "conventional."

There are many types of wisdom relating to the plurality of phenomena[1] and the fundamental nature of reality. We are concerned now with the supreme wisdom that acts as the antidote for the fundamental cause of the cycle

[1]Throughout this text the term "phenomenon" will be used synonymously with "entity," rather than as an antonym to "noumena."

of existence[2]--namely, grasping onto true existence--and the instincts[3] for such grasping, which are cognitive obscurations. Such wisdom is the view by which one realizes emptiness; one thereby knows the fundamental nature of reality.

We need to understand the essential nature of the broad diversity of phenomena. For example, if we are obliged to be involved frequently with a man who exhibits an immediate, surface personality and another basic personality, it is important for us to know both of them. To engage in a relationship with this person that does not go awry, we must know both aspects of his personality. To know only the facade that he presents is insufficient; we need to know his basic disposition and abilities. Then we can know what to expect from him; and he will not deceive us.

Likewise, the manifold events in the world are not non-existent; they do exist. They are able to help and hurt us--no further criterion for existence is necessary. If we do not understand their fundamental mode of existence, we are liable to be deceived, just as in the case of being involved with a person whose basic personality we do not know.

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[2]The cycle of existence is the condition of being repeatedly subject to birth, aging, sickness and death due to the power of mental afflictions and the actions that are tainted by them.

[3]vāsanā, bag chags

Now phenomena existing as dependently related events[4] are those that change in dependence upon circumstances and those that appear in various ways due to circumstances. All of the preceding teachings concern phenomena subject to change. They change due to their dependence upon other events[5]. If events existed independently, they could not change. Since they are dependent, they lack an independent nature. Thus, when something appears either good or bad, it seems to have that as an essential trait; but if we inspect matters more closely, we see that it is fundamentally subject to change. Thus, entities have two natures, one essential and the other superficial.

The physical world around us is impermanent, and individual entities have their own specific natures. Because the events that make up this world are dependent upon conditions, they lack an independent self-nature. That absence of an independent self-nature is the essential mode of existence of entities. Since events have two modes of existence--superficial and essential--there exist two types of cognition: one ascertaining the former nature and the other, the latter nature.

What is the essential mode of existence?: lack of independence, and lack of existence from the object's own

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[4] pratītyasamutpāda, rten cing 'brel bar 'byung ba

[5] The Sanskrit term dharma is translated in this work in three ways--entity, phenomenon and event--so those terms should be regarded here as synonymous.

side. The absence of intrinsic being is the ultimate mode of existence of an entity. The mind that apprehends that ultimate nature, which appears in accordance with its reality, cognizes reality as it is. It is thus called "ontological understanding."[6] That reality is empty because it is devoid of the mode of existence that is to be refuted; and for that very reason, it is called "emptiness." There is no higher truth to be seen. The mind that sees that reality experiences truth as it is. Thus it is called "ultimate truth," the essential mode of existence. For all other truths, their mode of appearance and their essential mode of existence are incongruent. Thus, they are called deceptive and superficial.

Now for a single entity we must understand two modes of existence. That entity, which is capable of benefiting or harming, has both modes of existence. We should not think of the fundamental nature of existence being found elsewhere. Its own essential nature is its ultimate mode of existence. Both a superficial and ultimate nature are to be found in a single entity, and those are the Two Truths.

The mind that ascertains the essential nature of an object is an intelligence that investigates the ultimate. The other mind is conventional intelligence, superficial cognition. When the text speaks of the need of developing wisdom, it refers to the former type of intelligence. In

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[6] ji lta ba'i shes rab

order to realize ultimate truth, one needs to distinguish between ultimate and superficial truths.

The text speaks of two objects of knowledge: conventional and ultimate truth. Both are to be known. Ultimate truth is not directly ascertainable by a dualistic awareness. When one directly apprehends the ultimate nature of an entity, dualistic appearances vanish. Thus, the ultimate transcends dualistic awareness. Dualistic awareness is polluted by ignorance, so that the ultimate cannot appear to it.

It would be absurd to say that the ultimate is not ascertained by any type of awareness at all. When the text says "Reality is not an object of the intellect," that intellect refers to dualistic awareness only. The first phrase--"Reality is not an object of the intellect"--entails a defining characteristic of ultimate truth; and the second--"the intellect is called 'conventional'"--entails a defining characteristic of conventional truth. The objects of dualistic awareness are conventional truths.

People Who Ascertain the Two Truths

3. Two types of people are found: the contemplative and the common person. The [view of the] contemplative person invalidates [that of] the common person.

There are two types of individuals--contemplatives and common people--i.e. those who engage in philosophical investigation and those who do not. Moreover, among the former there are higher and lower levels of investigation. Those who assert phenomenal identitylessness are on a higher lever; and those who deny it are on a lower level. Among the former are the Idealists[7], who advocate intrinsic reality, and above all are the Centrists[8].

Referring to those common people who do not engage in philosophical investigation, the text says that their way of seeing and describing the world [involving, for example, belief in a personal identity] is invalidated by the experience of those who do engage in such investigation. Likewise, the experience of those engaged in higher investigations invalidates that of people on a more simplistic level.

4. Even [the views of] contemplatives are invalidated by [those of] successively higher [contemplatives], due to the difference of insight, [which they can acknowledge] in terms of

[7]In this translation the term Idealist is used only with reference to the Buddhist idealist school known as Vijñānavāda (Tib. sems tsam pa).

[8]The term Centrist here refers only to the Madhyamika school (Tib. dbu ma pa) of Buddhist philosophy.

a commonly accepted analogy. [Whatever their views, they strive in virtuous acts] for the sake of spiritual growth, [leaving conventional reality] immune to their analysis.

As mentioned previously, the views even of contemplatives are invalidated by those of other contemplatives at higher levels of investigation. These views are invalidated by reasoning. Even among the Centrists there are two classes: Svatantrika [Independents] and Prasangika [Critics]. And among the Prasangikas there are different levels of contemplative insight even given the same set of postulates. For a single reality of emptiness there are different ways of experiencing it: an experience that is veiled with a general idea[9] and one that is not [e.g. on the Path of Seeing]. There are also distinctions in terms of the obscurations that successive insights are able to dispel. In each case the higher surmounts the lower.

If more simplistic views are logically annulled by higher ones, in order to recognize the refutation of own's own view, there must be a common basis of disputation. Here the author speaks of analogies that are accepted both by contemplatives and common people. For instance, dreams and hallucinations: When people in general remark that a

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[9]don spyi

certain experience was like a dream, that means that it did indeed occur, but they doubt whether it was real or true.

If as a result of scrutiny, different modes of existence are distinguished, does this mean that such spiritual activities as selfless giving are pointless? No, such methods of spiritual practice are to be adopted for the sake of spiritual growth, without examination or scrutiny.[10] Whatever appears to people is to be accepted conventionally and one practices on that basis.

5. Events are seen and also thought to be real by [common] people, and are not regarded as illusion-like. Here is the disagreement between the contemplative and the common person.

If contemplatives and common people are able to agree on a common basis of disputation, about what do they disagree? When spiritual teachings are given, there are bound to be different interpretations on many levels according to the subtlety and depth of insight of the listeners. For example, Realists assert the true existence of the body and mind; whereas Centrists assert that as

[10] If one applies ultimate analysis to the recipient of one's generosity, no person is to be found. This same negative result occurs is such investigation is applied to the giver and the act of giving. This conclusion, however, should not prevent one from acts of generosity. When engaging in such service, one regards the giver, the act of giving and the recipient in terms of conventional reality, without applying ultimate analysis to them.

lacking true existence: Even though they appear as true, they do not so exist, but are like illusions. Thus, on the basis of one teaching, different interpretations are made. In this way disagreement arises between contemplatives and common people.

Qualms Concerning the Lack of Intrinsic Existence

6. Form and so on, although perceived, are [established] by consensus; [their true existence] is not verifiably congized. Like the consensus that the impure and so on are pure and so forth, [such cognition] is false.

Qualm: If it is an error to think of form and so forth as real, how can it be that we verifiably perceive them? What further criterion beyond verifying perception is needed to establish the true existence of entities?

Response: Such entities are indeed verifiably perceived. However, when we say "verifying cognition"[11], this suggests infallibility. It is a non-deceptive awareness with reference to the appearance of a self-

[11] pramāṇa, tshad ma. For an explanation of the two major types of verifying cognition, perceptual and inferential, see F. Th. Stcherbatsky's Buddhist Logic (Dover Pub., Inc., N.Y., 1962) Vol. I, pp 146-180, 231-274.

defining object[12]. Realists--those who assert true existence--have just this in mind when speaking of verifying cognition. They believe that phenomena appear just as they exist, and they appear to be truly existent. They call a cognition that is non-deceptive with regard to that appearance "verifying."

Now in this [Centrist] context, infallible cognition is acknowledged, while denying that there is any such thing as even conventional intrinsic existence. Such cognition is said to be deceptive with regard to the appearance of phenomena as intrinsically existent. The Prasangikas, who hold this view, do not accept verifying cognition with respect to such appearance. Thus, they allow that a deceptive awareness may be verifying. Therefore, phenomena exist by the power of consensus, not by their intrinsic reality.[13]

Such phenomena as form are regarded as misleading, for their mode of appearance and their mode of existence are not

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[12] rang mtshan

[13] An entity does not exist by its own intrinsic being, but in dependence upon conceptual designation. In this sense it exists by the power of consensus; but, as the author points out, the mere fact that a certain group of people believe in the existence of something does not necessarily mean that it exists. For example, during the nineteenth century, there was widespread belief among physicists in the existence of absolute space and time. Although there was, roughly speaking, a consensus, that belief was erroneous.

A cognition may be mistaken with respect to the appearance of its object but not with respect to the object itself. For further reference to this point see footnote #25 to verse 75.

in accord with each other. Common people regard impure objects as pure, for the way those objects appear belies the way they actually exist.[14] Although they are thought by consensus to be pure, that conviction is false. Likewise, although phenomena are not truly existent, they appear as if they were; and thus they are asserted to be misleading.[15]

7. In order for common people to enter [gradually into an experience of ultimate reality], [real] entities were indicated by the Lord. One may object that if ultimately they are not momentary, that is contrary to conventional reality.

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[14] An "impure object" commonly cited in Buddhist literature is the human body. Sexual attraction toward the human body entails viewing it as something "pure" and desirable, and this appearance is enhanced by the use of perfume, jewelry and attractive garments. When the mind is dominated by lust, one focusses on the exterior of the desired body and associates it with desirable qualities. The contemplative whose mind is free of sensual craving sees that the body is "impure" as this term is normally used; for the outer skin is a container for such substances as blood, fat, bone, phlegm, sweat, excrement and urine. The deluded mind of a lustful person ignores the presence of there impure components of the body and falsely regards it as pure.

[15] To sum up, a community of people may agree as to the existence of certain entities and their ultimate mode of existence and yet be wrong. The fallacy of such beliefs is due to the fact that they are invalidated by verifying cognition; it is not because they fail to correspond to some independent, absolute reality. A central challenge of Buddhist mental training is to recognize the difference between deceptive and verifying cognition and to cultivate the latter. This is the purpose of the threefold training in moral discipline, concentration and wisdom.

Qualm: The Lord Buddha is recorded in the scriptures as saying that all composites are impermanent and all tainted things[16] are unsatisfactory. Thus, when the Buddha taught the Four Noble Truths, he spoke of sixteen attributes, including impermanence.[17] Are those not ultimate truths; are they not absolute?

Response: The Buddha taught these in order for people to enter into the experience of emptiness; but ultimately speaking, there is no such thing as the impermanence of a pot. Ultimately, events are not momentary. Ultimately, the object itself does not exist, so it has no properties such as impermanence.

Qualm: If one takes that position--that ultimately, events are not of a momentary nature--does that mean that the conventional presentation of phenomena as passing away moment by moment is incorrect?

8. There is no mistake, for [the wise, looking] upon the world see reality with the discernment of a contemplative. Otherwise, the conclusion that the female [body] is impure would be invalidated by common people.

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[16]"Tainted things" include those things that arise under the influence of mental distortions and the actions that ensue from such distortions.

[17]The Four Noble Truths, together with their sixteen attributes are discussed in Tibetan Tradition of Mental Development, pp. 20-38.

Response: No, that is not incorrect. That momentary nature is established by conventionally verifying cognition, so we accept that on a conventional basis. All the sixteen attributes of the Four Noble Truths are conventionally realized by contemplatives, so we can accept them.

Qualm: Well then, can we not call those sixteen "reality"?

Response: Common people mistake things that are essentially impermanent as permanent, and impure things as pure. In comparison to such attitudes, the contemplative experiences reality.[18] It is conventional reality.

Qualm: Since common people and contemplatives have two different ways of seeing things, might not the contemplatives' conclusions be invalidated by those of common people?

Response: No. There is the distinction that the former are backed by verifiable knowledge.[19] Otherwise, if

[18]To the untrained mind, the phenomena around us seem fairly static; only their gross impermanence is seen. The awareness of a contemplative, on the other hand, is refined to the point that the very subtle, moment-by-moment arising and passing of phenomena is ascertained. This subtle impermanence is an important facet of conventional reality.

[19]The mind of a contemplative is refined by means of a formidable training in stabilizing and clarifying awareness through the practice of meditative quiescence. It is then further developed with methods for the cultivation of insight. In this way verifiable knowledge is gained concerning both conventional and ultimate reality, and this invalidates the unfounded assumptions of common people.

the contemplatives' views could be repudiated simply by general consensus, then the conclusion that the female body is impure would be invalidated, since ordinary people think of it as pure and attractive.[20]

9. In [your] reality [real merit is accrued from revering a real Buddha]; likewise, [we assert that illusion-like] merit [is accrued] from [revering] an illusion-like Victor.
If sentient beings are like illusions, having died, how can they take birth again?

Qualm: If you deny true existence, do you still assert that one accumulates merit by making offerings to Awakened Beings and so on?

Response: Yes. One engages in illusion-like actions, and illusion-like fruits of those actions ensue. For example, Realists, who assert true existence, maintain that from real actions, real merit is accumulated and real results are experienced. The Centrists acknowledge the

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[20]Thus, the Centrist theory states very plainly that truth is not established by "majority rule." The insights of the enlighted few may invalidate the consensus of the masses. When Shantideva first orally presented this treatise, he did so before a congregation of monks; so it was appropriate for him to refer to the impurity of the female body as an antidote to lust. Were such a teacher to speak before an assembly of nuns, the reference would quite possibly be to the impurity of the male body.

accumulation of merit and the effects of actions--but as not truly existent.

Qualm: If sentient beings are like illusions, how can they take birth again after having died?

10. As long as complex of conditions [persists], so
long even illusion functions.
Why should a sentient being truly exist [more]
truly [than an illusion] by the mere fact of its
extended duration?

Response: An illusion in not truly existent. If an illusion appears as a horse or elephant, it does not exist as such. Although it is not real, it appears due to a complex of conditions, and it vanishes due to the cessation of that complex of conditions. So even an illusion depends upon causes and conditions. One cannot establish duration as a criterion for true existence.

11. There is no evil in such acts as the slaying of an
illusory person, for [such an entity] has no mind;
but in the case of one endowed with an illusory
mind, evil and merit are produced.

Qualm: Although sentient beings are like illusions, killing is evil. Is it also the case that killing illusory beings is evil?

Response: Since the being who is "killed" has no mind, no evil occurs.[21] But illusion-like beings have illusion-like minds, so helping or harming them results in merit or evil respectively.

12. An illusory mind is not [originally] produced, for incantations and so forth lack such a capability. Diverse conditions produce, moreover, a variety of illusions. Nowhere is there a single condition that has the ability [to produce] everything.

Mind is something that must arise from a source similar to itself, as will be explained later on.[22] There is no way

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[21] In committing a deed, four processes occur: (1) the intention, (2) the preparation, (3) the enactment and (4) the culmination of the act. In "killing" a mindless illusion of a person, the first two of those stages may occur, but not the latter two. Clearly the actual deed of killing and the resultant death of one's victim cannot occur, for no person exists in the illusion. Thus, the evil of slaying another person does not occur, but there is still the evil of the intent and the preparation.

[22] This subject is discussed in the commentary to verse 96. According to Buddhist contemplative science, the mind does not originate from matter or energy, nor does it arise from nothing. Rather, it can arise only in dependence upon a preceding mental continuum. Thus, the initial moment of consciousness of a fetus does not originate from the union of the egg and sperm of its parents. It must arise from a preceding continuum of consciousness. This continuum can be traced back to a previous life in which it was conjoined with another body that lived and died. The mind of a fetus thus carries innumerable imprints from previous lives.

that an incantation can freshly create a mind. So in an illusion there is no creation of an illusory mind. One may create illusory horses and elephants but not an illusory mind.

From diverse conditions, a variety of illusions arise. Even though they are not real, they are produced by various conditions. A single condition cannot produce everything.

13. If it were the case that while being ultimately emancipated, one were [still] to be conventionally subject to rebirth, then an Buddha would also be subject to rebirth. In that case, what would be the point of the Bodhisattva way of life?

In treatises such as Nagarjuna's Sixty Stanzas of Reasoning [23] there is reference to ultimate truth, the absence of intrinsic existence, as emancipation. The cycle of existence is conventional. There are three types of emancipation: natural, residual and non-residual.[24] The first of those is the mere absence of intrinsic existence. Thus, a single individual could abide simultaneously in the world and in emancipation. In reference to this, there is

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[23] Yuktiṣaṣṭikā, Rigs pa drug bcu pa

[24] Further reference to residual and non-residual liberation can be found in Meditation on Emptiness, pp 342, 394-395.

the question as to whether a Buddha is in the cycle of existence.[25]

14. If the conditions are not discontinued, even illusions do not cease. But due to the cessation of conditions, the conventional, too, does not occur.

Even illusions are dependent upon conducive conditions. If those conditions are not interrupted, neither are the ensuing illusions; and if the former cease, so do the latter. Thus, as long as the necessary conditions prevail, the cycle of existence, which is like an illusion, persists.[26] If those conditions cease, not only is there

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[25] A Buddha has gained release from the cycle of existence, but this does not imply, according to Mahayana Buddhism, that such a being no longer takes birth in the world. He [or she] does not take birth due to the force of mental distortions and the actions that are tainted by them. Rather, a Buddha appears in the world due to the force of compassion, in order to lead sentient beings to spiritual awakening.

[26] The Buddhist concept of the world as illusion is one that is commonly misunderstood and disdained by Western readers, especially those with an affinity for science. This is partially due to a large body of Buddhist literature in Western languages that misrepresents this theory; and, unfortunately, such authors frequently display a contempt for the use of the intellect and logic in probing the nature of reality. This distortion of the Buddhist teachings naturally creates unjustified barriers between the Buddhist and the Western scientific search for truth.

For example, when physicist Stephen Hawking was presented with the possibility that Eastern mysticism might yield insights into objective reality, he responded, "I think it is absolute rubbish...The universe of Eastern mysticism is an illusion. A physicist who attempts to link it with his own work has abandoned physics." [Stephen Hawking's Universe, John Boslough (William the natural emancipation of ultimate truth, even the conventional, momentary [i.e. rising and passing with each moment] continuum of the cycle of existence is cut. And that cessation is called emancipation.

For example, just as clouds vanish into an empty sky, so are the obscurations extinguished in the sphere of reality [27]. In that way the afflictive obscurations are dispelled by the influence of conditions, and thus they are eliminated even conventionally. That is called liberation.

Morrow & Co., Ind., N.Y., 1985) p. 127]. A first response to this objection is that much that goes under the name of "Eastern mysticism" is well described as rubbish, just as much that is called "science" is nonsense. However, the mere fact that Buddhism deems the world to be illusion-like hardly sets it at odds with Western science. The transcendental realism underlying most of physics states that nature is drastically unlike our direct experience of it; and both quantum mechanics and relativity describe a world very foreign to our ordinary perceptions and concepts. In that sense science deems everyday experience of nature as illusory.

The Centrist view acknowledges the existence of a physical world every bit as real as mental events, and it states that physical theories may be true of nature insofar as they are based on verifying experience. In this way it avoids the extreme of instrumentalism. However, science does not represent nature as it exists independently of our experience and concepts; and with this statement the Centrist view shuns the extremes of both immanent realism and transcendental realism.

[27] dharmadhātu, chos kyi dbying

CHAPTER TWO:

CRITIQUE OF THE IDEALIST VIEW

15. If even deceptive [cognition] does not exist, by
what is illusion ascertained?

Since the Centrists deny the true existence of all entities, then the awareness of illusion-like forms and so forth must be devoid of an intrinsic identity. So, when an Idealist hears that something lacks an intrinsic nature, he [or she] concludes that it is utterly non-existent. And thus he [or she] asks: If even the cognition of an illusion does not exist, by what is the illusion known? The implication is that it would be ascertained by nothing at all. To this the Centrist replies:

16. If for you illusion itself does not exist, then
what is to be ascertained? You may respond that
in reality it exists otherwise, simply as an
expression of the mind.

Idealist: External objects do not exist. All possible entities are of the nature of the subjective mind. They are substances of the mind, lacking any other substance. We

Idealists take as our scriptural source the statement that the three realms of existence[1] are of the nature of the mind.

Centrist: According to you, if entities existed externally, as they appear to, they would not be illusory. If they do not exist externally, despite appearances, they would be devoid of an intrinsic nature; and in your view that would make them utterly non-existent. In that case, if the illusion itself does not exist, then there would be nothing to ascertain.

Idealist: In reality an entity does not exist externally, as it appears. Phenomena, such as form, exist otherwise--as substances of the mind that apprehends them. Thus, they do not exist as external objects, nor are they utterly non-existent.

17. If the mind itself is an illusion, then what is seen by what? For the Protector of the World has said that the mind does not perceive the mind. Just as the blade of a sword cannot cut itself, so is it with the mind.

Centrist: You Idealists maintain that the mind is of the same nature as the object that it apprehends. If the

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[1] dhātu, khams. The three are the sensual realm, the form realm and the formless realm.

subject and object are identical, how can anything be seen by anything? The scriptures also refute the possibility of something apprehending itself. In the Crown Jewel Discourse[2] the Buddha states that the mind does not perceive itself. The mind cannot see itself just as a blade cannot cut itself.

18. You may reply: It is like a lamp illuminating
    itself.
    A lamp does not illuminate [itself], since
    darkness does not conceal [itself].

Idealist: Just as a lamp illuminates the surrounding darkness, so does it illuminate itself. There may be the tacit assumption that if it cannot illuminate itself, it could not illuminate anything else. Likewise, just as awareness perceives other objects, so does it perceive itself.

Centrist: It is conventionally inappropriate to say that a lamp illuminates itself. Why? Because a lamp does not have the quality of darkness. If darkness is present, it can be dispelled, but since this is absent in a lamp, it is meaningless to speak of a lamp illuminating itself. This

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[2] Cūḍāmanisūtra, bTsug na rin po che'i mdo

point is discussed at length in Nagarjuna's Fundamental Wisdom[3].

19. A blue [thing] does not require another [blue thing] for its blueness, as does a clear crystal. So the mind is seen sometimes to depend on another, sometimes not.

Idealist: For example, if one were to place a clear crystal on a blue base, its blue appearance would be dependent upon some other blue substance. Now something like a lapis luzuli gem is blue from the very time it is created, so its blueness does not depend upon another blue substance. Thus, just as there are the two cases of dependence and lack of dependence on another object, so are some cognitions dependent upon objects such as form, while others are focussed inward and perceive awareness only.

Centrist: To determine whether forms and so on exist, it is indispensable to have verifying cognition: If something can be apprehended by an verifying cognition, it exists; if it cannot, it does not exist. In fact "something that can be ascertained by an verifying cognition" is the definition of something having a basis in reality[4]. All [Buddhist schools] agree on this point. Therefore, if

[3] Prajñāmūla, rTsa ba'i shes rab

[4] gzhi grub

there is no verifying cognition to establish the existence of something, one cannot claim that it exists. When one claims that there is verifying cognition of something, such as an objective form, one cannot prove that that cognition is verifying simply on the grounds that it has an object; nor can one claim that that object exists simply on the grounds that it is apprehended. That would be circular reasoning. The problem arises from the [Realists'] inability to establish the existence of an object and the verifiability of a cognition purely on a conventional basis. Thus, to establish the validity of one cognition, one would need another verifying cognition to apprehend it...and another would be needed to establish its verifiability, _ad infinitum_. This is a fallacious approach.

Thus, the Idealist speaks of a self-ascertaining, verifying cognition that apprehends verifying cognitions. That cognition establishes the verifiability of cognitions. For example, the visual perception of form is dependent upon another object. But another type of awareness apprehends itself and does not depend upon another object: The seer and the seen are not different.

20. Such blue [-ness of a blue thing] is not regarded
as the cause of [its own] blueness, as in the case
of the non-blueness [of a crystal, where there _is_

causation]. What blue would make just blue, itself [made] by itself?

Centrist: The blueness of lapis lazuli is created by other conditions; it is not created by itself.

21. The statement that a lamp illuminates is made upon knowing this with awareness. The statement that the mind illuminates is made upon knowing this by what awareness?

Centrist: Upon analysis, a prior awareness does not apprehend an awareness in the present that has not yet arisen at the time of the prior cognition. A later awareness does not apprehend an awareness that has arisen and already passed. An awareness in the present cannot be both a subject and its own object. Thus, according to the system that asserts that the designated object[5] is found upon analysis, by means of what cognition is awareness said to be clear?

22. If nothing observes whether it is illuminating or not, to speak about it is foolish, as in the case of the beauty of a barren woman's daughter.

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[5] gtags don

Centrist: We, who recognize the analytic unfindability of sought referents, maintain that there is no cognition that sees this; so one cannot state whether it is illuminating or not. It would be like speaking of the beauty of a barren woman's daughter--it is nowhere to be found.

Idealist: It is necessary that awareness illuminate itself, as stated above; and this assertion is needed to establish verifying cognition. Thus, there is self-cognizing awareness [6].

23. [Idealist:] If there is no self-cognizing awareness, how is consciousness recalled?
[Centrist]: Recollection is due to the connection with the perception of something else. This is like the poison of a rat ['s bite].

Idealist: In order for recollection to occur, there must be prior experience. Without prior experience, there can be no recollection. There is the twofold classification of "self-experience" and "other-experience." If the experience [of one's own consciousness] is an other-experience--i.e. an experience of some other entity--infinite regress ensues. Therefore, such experience must be self-experience [i.e. an awareness of an entity that

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[6] svasaṃvitti, rang rig

is of the same nature as the awareness itself]. Thus, the experience must be one in which there is awareness of itself, otherwise recollection could not occur. For example, from a prior perception of blue, there later occurs the recollection of the object--blue--and the recollection of the subject--"I saw blue." Therefore, together with a prior experience of the object, there was self-cognizing awareness of the subject--the visual perception of blue. In that way there can occur a later recollection that "I saw blue."

Centrist: There is no need to experience something in order for it later to be recalled. For example, while one is unaware, one might be bitten and thereby poisoned by a rat. Although one experiences being bitten, one does not experience the invasion of the poison into one's body. Although that is not perceived, later, when the effects of the poison are felt, one recalls that while unaware, the poison was injected.

Likewise, due to the perception of blue, one later recalls the visual perception of blue; but for that to occur, it was not necessary for that perception to experience itself. How does that recollection arise? Upon experiencing the other object-blue--due to the connection between the subject and object, recollection [of the former] occurs. So there is no need first to experience the subject.

24. [Idealist]: In a different circumstance, [the minds of others] are seen, so [the mind must also] illuminate itself.

[Centrist]: A pot is seen due to the application of an empowered eye-ointment, but the ointment itself would not be seen.

Idealist: Upon attaining meditative quiescence, it is possible to perceive the minds of other distant people.[7] Thus, it must be possible for one's own mind to be perceived by itself.

Understand the specific point being refuted here. This refers to the refutation of the [Idealist's theory about] mind perceiving itself. For example, one must recall that it is possible to cultivate meditative quiescence which is focussed upon the mind.[8] This discussion concerns a single awareness perceiving itself. The Idealist argument, once again, is that if it is possible to observe the minds of other distant beings, there could be no flaw in the statement that awareness perceives itself, which is right at hand.

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[7]For a method to develop such awareness see Buddhaghosa's The Path of Purification, trans. Bhikkhu Ñāṇamoli (Buddhist Pub. Soc., Kandy, Sri Lanka, 1979) XIII, 8-12.

[8]For an explanation of this practice see Geshé Rabten's Echoes of Voidness (Wisdom Pub., London, 1983) pp. 113-128.

Centrist: The fact that one can see something distant does not necessarily imply that one can see something else close by. For example, by the use of a special eye-ointment it may be possible to observe a buried pot of treasure; but the ointment itself would not be seen. According to our understanding of the analytic unfindability of sought referents, it is not possible for awareness to observe itself. When one analyzes former and later moments of awareness and seeks the designated object, it is not to be found. In this way, the Idealist presentation falls apart, i.e. it cannot be applied to reality.

Idealist: Do you Centrists refute the entire presentation of cognition, including the experiencing, seeing and hearing of events? If you take the above stance [with regard to self-cognizing awareness], this invalidates awareness.

25. Here that which is seen, heard and cognized is not
refuted; rather, the conception [of them] as truly
existent, which is the cause of suffering, is here
to be prevented.

Centrist: With regard to cognition, if one seeks the designated object, it is not to be found. But [the cognized object] is not invalidated or refuted by such reasoning. Although it exists, if one seeks it with reasoning [by applying ultimate analysis], it is not found. It is not truly existent, so when reasoning seeks a truly existent entity, none is found. But the fact that it is not found under such analysis is not because it is simply non--existent.

This form of logical analysis has the purpose of eradicating the conception of true existence, which acts as the root of attachment and hostility and brings suffering to individuals.[9] It is reasoning entailing ultimate analysis. If that which is denied-an ultimately existent entity--did exist, then things would exist by their own mode of existence[10]. If that were the case, then when applying logical analysis, [truly existent] things should present themselves. The function of such analysis is to check whether entities exist by their own mode of existence or not; so if they do, that should be discovered by such analysis. But since such analysis yields a negative result, that reasoning repudiates ultimate, or true, existence. That is

[9]Here is one of innumerable references in Buddhism to the close relationship between morality and inquiry into the nature of reality. Ignorance in the form of actively misaprehending reality is regarded as the fundamental distortion of the mind, and it is the source of other afflictions such as craving and hostility. Such mental distortions move people to evil behavior, and this is the source of strife and misery. Thus, the Buddhist quest for truth is not an amoral pursuit, as is so much of Western science. Rather, insight into the nature of reality is sought together with the cultivation of such virtues as lovingkindness and patience.

[10]gnas lugs su grub pa

the difference between something not being found by reasoning, and something being invalidated by reasoning.

Here cognition is not repudiated; rather, the conception of true existence, which is the cause of suffering, is to be dispelled.

26. [Idealist]: Illusion is not different from the mind, neither is it regarded as non-different.
[Centrist]: If it really exists, how can it be non-different [from the mind]? If it is non-different [from the mind], it does not exist in reality.

Idealist: Since external objects[11] do not exist, they are not substantially distinct from the mind. Nor do they exist as mind. Form and so on do not exist as external objects, but they are not simply non-existent. They are not of a different nature than the mind, nor are they the mind itself.

Centrist: If external objects truly exist, they would have to exist in the manner in which they appear; and in that case, they would have to be substantially different from the mind. Now, if they are not substantially different, and if manifold images[12] are truly of the nature

[11] bāhyārtha, phyi don

[12] rnam pa

of a single cognition, then those images would be deceptive. In that case, the cognition would not exist in reality. If they are not substantially different, they would not truly exist.

27. [Idealist]: Although illusion is not truly existent, it is something observed.
[Centrist]: Likewise, the mind [although not truly existent] is an observer.
[Idealist]: Cyclic existence has a basis in reality; otherwise, it would be like space.

Idealist: Forms and so forth appearing as external objects are not truly existent; i.e. they do not exist as external objects. They are devoid of such existence, and thus they are like illusions. Nevertheless, they are observed.

Centrist: In the same way, the mind, which is the observer, appears to be truly existent, but is not. Thus, it too can be regarded as illusion-like. So there is no need to assert the mind as truly existent. Although external phenomena appear, they are not truly existent; and thus they are considered to be illusion-like. In the same manner, the observing mind appears but is not truly existent; and it is therefore regarded as illusion-like. Where is the fallacy in such reasoning?

Idealist: Cyclic existence, forms, imputed entities[13] and so on each require a truly existent basis for their deceptive appearance. That is, each has to have a basis in reality. If they lacked such a basis, they would be like space. Thus, they would not be a source of either benefit or harm.

28. Since the dependence on reality is of a non-real [thing], could it have any efficiency ? The mind, according to you, is reduced to a state of isolation without any accompaniment.

Centrist: If cyclic existence and so on, being unreal[14], depended upon a real basis of their deceptive appearance, how could they have any function? You say that if they did not depend upon such a basis, they would not have the function of binding or liberating sentient beings; and there could be no alteration in that which has such a basis. Since there could be no change, there would be no bondage or liberation.

If there were no external objects, the mind, as you assert it, would be isolated in its own self-illuminating self-cognition, without the accompaniment of the dualistic, deceptive appearance of subject and object.

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[13]gtags yod

[14]abhāva, dngos med

29. If the mind were separated from its apprehended object, then all beings would be Tathagatas. So what good is gained by regarding [entities] as mind only?

Centrist: If the mind were freed of the dualistic appearance of subject and object--e.g. in a state of meditative equipoise--then all sentient beings would be Tathagatas [Buddhas] long ago. By turning away from the basis of dualistic appearance, they would abide in the sphere of reality and would have become Tathagatas already.

If that were the case, what is the point in your setting forth the Mind-only view in order to escape the bondage of mental distortions?

CHAPTER THREE:

THE NECESSITY OF THE CENTRIST PATH

The Necessity of Realizing Emptiness

30. Even if one knows [something] to be like an illusion, how does this prevent mental distortions? Lust for an illusory woman may arise even in her creator.

Now the author presents rebuttals of criticisms of the Centrist view:

Objection: You Centrists present the view that all entities are like illusions. By cultivating that understanding, one cannot avert mental distortions. It is a proven fact that a magician may feel lust for his own creation of the illusion of a woman. So merely recognizing something as an illusion is not enough.

31. For that creator, the instincts of mental distortions toward objects have not been eliminated. Thus, when he sees [the illusory woman], his instinct for [understanindg] emptiness is very weak.

Rebuttal: The creator of the illusion, upon seeing the attractive appearance of the illusory woman as truly existent, has not yet eradicated the instincts of mental distortions. So he grasps onto her true existence, and under that influence, mental distortions arise. Although he knows that the illusory woman is "empty" of existence as an actual woman, mental distortions arise with regard to her attractive appearance. Why? Because he still grasps onto the true existence of the illusory woman, and this leads to lust for her. Thus, the understanding of the emptiness of the illusory woman has not been deeply cultivated.

32. By building up instincts of [understanding] emptiness, the instincts of [grasping onto] reality are eliminated. And by cultivating [the realization that] nothing whatever is [truly existent], [the instinct for grasping onto the true existence of emptiness] too, will eventually be discarded.

If one builds up instincts for [understanding] emptiness, by logically establishing all entities as being empty of true existence, experientially realizes this, and repeatedly enters into that experience, then the instincts for [grasping onto] reality can be dispelled.

If one perceives the absence of an intrinsic nature in forms and so on, then when such phenomena appear, they can be seen as deceptive, or not truly existent. Then when one looks upon attractive or unattractive phenomena, and attachment or aversion arise, one can actually ascertain that they do not truly exist-despite appearances to the contrary. This will diminish the arisal of attachment and aversion, which result from the conception of events existing in the manner in which they appear. This false way of apprehending things has been with us since beginningless time.

First one ascertains the lack of an intrinsic nature in forms and so on. When one gains an understanding of this emptiness of such things, one investigates the mode of existence of that emptiness. One finds that it, too, is devoid of intrinsic being and exists merely by the power of convention. This is the emptiness of emptiness. Emptiness itself is not truly existent.

Thus, first one investigates the ultimate nature of things such as forms, and by ascertaining their emptiness of intrinsic existence, craving and aversion toward them are decreased. Then one investigates the nature of emptiness and discovers it to have only conventional existence. As a result, one does not conceive of emptiness as being truly existent. Then when emptiness is ascertained, apart from cutting away the object of refutation, the mind does not conceive of anything. The mind stops with the sheer ascertainment of the absence of intrinsic existence and abides in that experience of emptiness, which is the absence of the object of refutation. There is no thought that "this is emptiness" or "this is the absence of intrinsic existence." There is only the awareness of the absence of intrinsic existence.

33. When something is not apprehended and it is considered as non-existent, then how can this non-entity, which has no foundation, remain before the mind?

When one is investigating an object to determine whether or not it is truly existent, one eventually arrives at the conclusion that the object does not exist in the way that it appears. At that moment, nothing appears before the mind except the emptiness that is the absence of the object of refutation. When this cognition wanes, one should repeatedly bring to mind the arguments for the lack of intrinsic existence and thus reinforce the strength of one's investigation. It is important to maintain the experience of the sheer emptiness of the object of refutation, i.e. the ascertainment of the absence of intrinsic existence.

34. When neither a [truly existent] entity nor a [truly existent] non-entity remains before the mind, then since there is no other alternative, [the mind,] being without the objective support [of grasping onto true existence], is calmed.

This stanza refers to the Path of Superior Beings[1]. By repeatedly cultivating the awareness of emptiness, one eventually realizes that all events are devoid of intrinsic existence. First one receives instruction in the appropriate treatises from a spiritual mentor. One thereby gains understanding based on the verses of the texts. This is understanding due to hearing. Then by patient investigation and repeated reflection there arises a sense of certainty due to reflection. This entails an understanding of the view that all entities are devoid of intrinsic existence.

Now in order to gain perfect certainty of the view, it is probably necessary to have the support of meditative concentration[2]. When the mind has little stability--or capacity of single-pointed concentration--it is unlikely that one could profoundly ascertain the absence of an intrinsic nature of all entities for longer that a fleeting instant. So one needs the aid of concentration. With that,

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[1]āryamārga, 'phags lam

[2]samādhi, ting nge 'dsin

one eventually gains understanding due to meditation, focussed on emptiness; and it is stable.

This is discussed in explanations of the Path of Preparation.[3] During the four successive stages of the Path of Preparation, dualistic appearance becomes increasingly subtle. Finally, at the initial moment of realization of emptiness on the Path of Seeing, all dualistic appearances, even the most subtle, are completely gone. Then, like water pouring into water, there occurs an experience with no sense of a distinction between subject and object.

By cultivating that realization, there finally occurs the diamond-like concentration[4] on the Path of Meditation. That acts as the direct remedy for cognitive obscurations, and omniscient wisdom arises. As long as one is not yet fully awakened, when non-conceptual, meditative realization of emptiness occurs, all conceptual elaborations are pacified. But dualistic appearance returns when one arises from meditation. However, once omniscient wisdom arises, all conceptual elaborations vanish, and they never recur. Then the attributes of the full fruition of the path of awakening arise.

35. Just as a wish-fulfilling gem and a wish-granting
tree satisfy all desires, in the same way the

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[3] cf. Footnote #5 to verse 1.

[4] vajropamasamādhi, rdo rje lta bu'i ting nge 'dsin

image of the Victor is considered [to fulfill all desires, motivated] by the [needs of] disciples and the vows [of the Awakened One].

Upon full awakening, the mind is not moved the tiniest bit by conceptions of motivation and effort. However, by the force of the merit of disciples and the Awakened Being's own previous altruistic prayers, the body of a Victor appears instantly to disciples in pure and impure realms.[5] The body appears effortlessly, by the power of prayer.

36. If an alchemist dies after producing a pillar, even if a long time had passed since his death, it would still neutralize poisons and so on.

For example, even if a long time has passed since the death of a brahmin who prepared a medicinal pillar, by the power of his previous prayers, if one worships at that pillar, poisons and so forth will be neutralized.[6]

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[5] Impure realms of existence are those that come into being by the power of mental distortions and the actions that ensue from such distortions. According to Buddhist cosmology, the world in which a community of sentient beings dwells is brought into existence by the former deeds of the members of that community. No transcendent Creator is needed for the creation of worlds. A pure realm is one that is brought about by the prayers of an Awakened Being, and it is untainted by mental distortions and the actions that ensue from such distortions.

[6] Shantideva makes reference to such strange phenomena as "medicinal pillars" as if their existence was commonly accepted by his contemporary audience. The classical Indian civilization

37. Likewise, the "pillar" of the Victor's [body] is created in accordance with the Bodhisattva's deeds; and though the Bodhisattva has passed away, he [or she] still accomplishes all necessary works.

Also when the pillar [i.e. body] of the Victor is produced, in accordance with the Bodhisattva's actions, all deeds are
performed even though the Bodhisattva has passed away. These are done effortlessly.

38. If [an Awakened Being has] no [conceptual] mind, how could worshiping [such a person] be fruitful? Because it is written that [the value is] equal whether [the Awakened Being] is present or passed away.

Since conceptualizing has vanished from the mind of a Tathagata, how could it be helpful to worship such a being? It is beneficial because it is said there is just as much value in worshiping a Buddha while he [or she] is present on

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of his time abounded in "psychic technology" due to its advanced contemplative science. In the intervening centuries this civilization was ravaged by various peoples from the West, and much of its science and technology was lost.

earth as there is in worshiping the relics of such a being after he [or she] has passed into Nirvana.

39. Whether [that worship exists] conventionally or in reality, the scriptures [state that] there is a fruitful effect. It is, for example, like the fruitfulness of worshiping a truly existent Buddha.

Centrist: I maintain that the merit that accrues from worshiping an Awakened Being exists merely conventionally. You assert that it is truly existent. Either way, we agree that there is benefit in worshiping a Buddha who has passed into Nirvana. For example, you Realists believe that it is fruitful to worship a truly existent Buddha. I believe that illusion-like merits are accrued from the worship of an illusion-like Buddha. But we agree that such worship is fruitful.[7]

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[7]The realist looks upon the causal relations between natural events as a compelling reason for believing that they exist in their own right, independent of conceptual designation. If they were dependent upon such designation, how could they ever interact among themselves? The Centrist replies that if events were truly existent, they would be utterly immutable and isolated from one another. Each entity would intrinsically bear its own static attributes, and it would exist eternally. This would preclude any possibility of causal interactions among phenomena. In short, the Centrist concludes that causal relations are possible only because events are not truly existent.

40. Liberation is gained from seeing [the Four Noble] Truths, so what is the point of perceiving emptiness?
The scriptures state that there is no spiritual awakening without this path.

Shantideva declared previously that it is necessary to stop grasping onto true existence and to realize emptiness. Here is an objection:

In order to become omniscient, one must realize emptiness, but such realization is not needed simply to gain liberation from cyclic existence. By cultivating the path of wisdom of the Four Noble Truths, with their sixteen attributes, it is possible to dispel the mental afflictions that are brought on by grasping onto a self-sufficient, substantial personal identity. By subduing such afflictions one can attain liberation, so there is no need to meditate on emptiness.

Moreover, the view of emptiness that is included among the sixteen attributes of the Four Noble Truths is declared to be the liberating path of wisdom. The other attributes are said to be preparatory paths. Thus, by meditating on the emptiness and identitylessness that are included among the sixteen attributes, one can attain liberation. So what is the point of meditating on emptiness [as it is set forth in the preceding verses]?

Rebuttal: In many of the definitive discourses of the Buddha, it is said that if one grasps onto reality, lacking the view of emptiness, there is no liberation. All the stages of awakening, from the stage of Stream Entry to becoming an Arhat[8], require realization of emptiness. Those sutras state that people wishing to follow the spiritual paths of Listeners, Solitary Sages and Bodhisattvas should all train in transcendent wisdom. Thus, all three states of awakening are impossible without such realization.

41. Now it may be said that the Mahayana [scriptures]
are not established [as the Buddha's teachings].
On what grounds is your own [Hinayana] canon so
established?
Because it is granted authenticity by both of us.
Then yours was not authenticated from the start.

Objection: The scriptures cited above are Mahayana sources, but it is doubtful whether those discourses are Buddha's words. So you cannot prove your point by citing sutras whose authenticity is in question.

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[8]These four stages are (1) Stream-entry, (2) Once-Returner, (3) Non-Returner and (4) Arhat (Liberated Being). For an explanation of these stages according to Theravada Buddhism see Paravahera Vajirañāṇa Mahāthera's Buddhist Meditation in Theory and Practice (Buddhist Missionary Society, Jalan Berhala, Kuala Lumpur 09-06, Malaysia, 1975) ch. 30.

Hinayana canon simply on the grounds that two parties--the Hinayanists and the Mahayanists--
agree on this, then the Vedas would also be the truth.[10]

43. You may say that the Mahayana [is to be rejected since its authenticity] is contested. Then since [the validity of the entire Hinayan canon] is contested by non-Buddhists, and certain other [Hinayana] scriptures are contested by your own and other [Hinayana orders], reject them [too].

One might take the position that the Mahayana canon should be rejected since it is contested by Hinayanists. But that is a poor reason. The validity of the Hinayana canon as a whole is accepted by some and rejected by others. Moreover, Extremists[11] do not believe in the Buddhist scriptures. So the validity of the Hinayana canon is also contested. Disagreement also occurs among Hinayana schools.

Thus, the contention that the Mahayana scriptures are not the Buddha's words is not only a contemporary issue. Arguments for the authenticity of the Mahayana are found in

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[10]Once again the point is clearly made that truth is not determined merely by consensus. It must be established by verifying cognition, of which there are basically two kinds: perceptual and inferential. There are various forms of perceptual verifying cognition, and one of them is the heightened awareness that a contemplative cultivates through meditation.

[11]tīrthika, mu stegs pa

Shantideva's writings, in Nagarjuna's Jewel Garland[12] and in Maitreya's Ornament for the Sutras[13]. The fact that its authenticity has been contested is quite understandable. In the Mahayana sutras many extraordinary mysteries are discussed which the minds of ordinary beings like ourselves cannot fathom. When one fails to comprehend such explanations, one tends to doubt their validity.

Nevertheless, if only the Hinayana and not the Mahayana sutras were Buddha's teachings, then Buddhist spirituality would be impoverished by the absence of the latter. Moreover, if the Mahayana canon were not the Buddha's teachings, then one could ask whether it is possible to attain omniscience, or the state of Buddhahood, by means of the thirty-seven elements of the Hinayana path.[14] Even the Hinayana scriptures acknowledge the different spiritual paths of a Listener, a Solitary Sage and of a Bodhisattva.[15] How does one proceed on the Bodhisattva path? How is the awakening of a Buddha experienced? It would be exceedingly difficult to set out on that path solely on the basis of the Hinayana scriptures, without the Mahayana.

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[12] Ratnāvalī, dBu ma rin chen phreng ba

[13] Sūtrālaṃkāra, mDo sde rgyan

[14] cf. Buddhaghosa's The Path of Purification, trans. Bhikkhu Ñāṇamoli (Buddhist Publication Society, Kandy, Sri Lanka, 1979) XXII 33-43.

[15] cf. ibid., III 128, IV 55, XIII 16.

Most importantly, one cannot attain the Nirvana [of Buddhahood] solely on the basis of the Hinayana treatises, nor can one realize emptiness. Without realization of emptiness, Nirvana cannot be attained, in which case the "Truth of Cessation" is reduced to mere talk. Thus, if the authenticity of the Mahayana is not established, it is virtually impossible to grant the authenticity of the Hinayana.

Now it is well known in Buddhist tradition that historically three compilations of the Buddha's teachings occurred. On the first occasion, the three "baskets" of the Buddha's teachings[16] were assembled, and there is no reference to a Mahayana compilation. In the celebrated, early historical accounts there is no mention of the Mahayana, and this gives rise to questions. But I do not think this is problematic.

The widely celebrated teachings that the historical Buddha gave in India are the Hinayana discourses. But apart from those, I believe he gave Mahayana teachings to a small number of beings who were pure in action[17]. For example, it is unlikely that Vultures Peak in India was massive during

[16] These three baskets are (1) Vinaya, dealing with moral discipline, (2) Sutra, dealing with the training in meditative concentration and other facets of the path of awakening, and (3) Abhidharma, (sometimes translated as "higher knowledge") concerning a diversity of topics ranging from psychology to cosmology. For a further explanation see Opening the Eye of New Awareness, pp. 47-52.

[17] las dag

the time of the Buddha, whereas now it is quite small. It was probably the same size then. In the Mahayana sutras there are accounts of the Buddha teaching on Vultures Peak in the midst of thousands of Arhats and hundreds of thousands of Bodhisattvas. It would seem that there would not be room for such an assembly. Let alone the gods in the congregation, who have subtler bodies, there is not sufficient space on that little hill to accomodate even that number of human beings. So I do not think they were all assembled on that hill as we perceive it.

When the Buddha gave Mahayana teachings there, they were heard by disciples who were pure in action; and to them that site appeared broad and vast. The Buddha did not offer Mahayana teachings to the general public; they would not have been of benefit. His most public, or celebrated, discourses were given in the presence of such Listeners as Shariputra and Maudgalyayana. In the circle of his disciples who were pure in action were Maitreya, Manjushri and so on--Bodhisattvas who appeared in the form of gods. To such disciples the Buddha appeared to teach in the presence of these beings as well as Listener disciples.

Now to the smallest number of disciples of extraordinarily pure action the Buddha gave tantric teachings.[18] To some such disciples he generated a mandala

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[18]For a brief introduction to the meaning of tantra in the Buddhist context see <u>Opening the Eye of New Awareness</u>, pp. 95-105.

with himself as the deity within it, engaging in meditative concentration on the non-duality of the profound and the vivid reality[19]; but the chief deity in the mandala appeared in the form of the Buddha as a monk. Then the even subtler mysteries were taught to disciples of even greater purity who, by practicing higher forms of method and wisdom, gained realization of non-dual ultimate and phenomenal reality. For such disciples there were no obstructions to the Buddha casting off the form of a monk and appearing as a richly adorned deity or as a Universal Monarch. For them it was very meaningful for the Buddha to appear in such guises.

It is not possible for gross consciousness to transform into omniscient wisdom; only a subtle mind can be so transformed. To facilitate this the Buddha revealed practices to focus the mind on the channels, energies and drops of the subtle human anatomy.[20] There were given only to those disciples of the utmost purity.

Thus, to disciples of increasing purity, ability and rarity the Buddha gave more private guidance in the subtle mysteries. It appears that such teachings are included in the Mahayana sutras. There is no certainty, however, that all of the tantras were taught while the historical Buddha

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[19] zab gsal gnyis med

[20] These are explained in <u>Death, Intermediate State and Rebirth</u>, Lati Rinbochay and Jeffrey Hopkins (Snow Lion Pub., Inc., Ithaca, N.Y., 1985). See also Geshe Kelsang Gyatso's <u>Clear Light of Bliss</u> (Wisdom Pub., London, 1982) pp. 17-32.

was alive. To an extremely small number of pure disciples the Buddha could appear today. They could encounter Vajradhara, the King of the Tantras. He could reveal tantras and quintessential guidance to them. This is possible even though more than twenty-five hundred years have gone by since the historical Buddha passed away. There is no possibility, after the Buddha's death, of additions being made to his public discourses. But I think that teachings to disciples of pure action do not necessarily have to be given during the historical Buddha's lifetime. That is my opinion.

Nowadays there are people who object to the terms "Mahayana" and "Hinayana." They regard the latter term, meaning "Lesser Vehicle," as pejorative, or disparaging, and declare this to be a source of discord among Buddhists. This is something to be considered. The distinction of "Great Vehicle" and "Lesser Vehicle" was not made to demonstrate contempt for the latter. Followers of the Mahayana should study and practice the Hinayana teachings. The distinction between the two Vehicles is made in terms of their differing presentations of (1) the basis of spiritual practice, (2) the extent of the motivation and practice along the spiritual path and (3) the degrees of awakening due to differing levels of purity and realization. Thus, the terms were not created out of disrespect or sectarianism. Basically there is nothing wrong with these labels, though they have become somewhat uncomfortable to use. For this reason there are people who think we should dispense with them.

We did not create these two terms. They are found in the great Buddhist treatises of classical India, and the Buddha himself used them frequently, as recorded in the Mahayana sutras. If this dual classification is deemed fallacious, it is not we today who are in error; it rather implies that the Buddhist classics are at fault and that the Buddha was sectarian. So I do not think there is any point in dispensing with these terms.

Some people suggest that we use the terms "Listener Vehicle," "Solitary Sage Vehicle" and "Bodhisattva Vehicle." Those are found in the Hinayana scriptures and they are in accord with the Mahayana. Thus, one could simply not use the former two terms and use these three instead, without condemning the former.

44. You might insist that the root of the teachings is
    the monkhood. But it is implausible that those
    monks [were Arhats]. For those whose minds are
    subject to grasping [onto true existence], Nirvana
    is implausible.

Now begins a logical argument for the authenticity of the Mahayana. Without the view of emptiness as it is revealed in the Mahayana sturas, it is impossible to attain any of the three states of awakening. If one takes the position that the root of the teachings is the monks who are Arhats, Shantideva replies: If those monks do not assert emptiness, they could not be Arhats. Why? Because if one lacks realization of emptiness, mental distortions cannot be eliminated; and if they are not eliminated, one cannot become an Arhat. Thus, the root of the teachings could not be monk Arhats.

In short, if the mind is still subject to grasping onto true existence, Nirvana cannot be attained.

45. You may say that by eliminating mental distortions, they would immediately be liberated. But for them the effectiveness of tainted action is still in evidence, even without mental distortions [as explained in the Abhidharma].

Vaibhashika: Those monks would indeed be Arhats, for by meditating on the sixteen attributes of the Four Noble Truths as explained in the Abhidharma treatises, the mental distortions can be eliminated. And by eliminating them, liberation is gained.[21]

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[21]For an introduction to Vaibhashika philosophy see Th. Stcherbatsky's The Central Conception of Buddhism (Motilal Banarsidass, Delhi, India, 1974) pp. 76-91.

Centrist: That is incorrect. You maintain that the subtle state of mind that grasps onto the intrinsic nature of entities is in accord with reality. You fundamentally assume that all entities are truly existent. You believe that it is realistic to apprehend phenomena according to the way they appear--viz. as truly existent. You explain mental distortions such as attachment and hostility in terms of those that are produced by grasping onto a self-sufficient, substantial self. Those are far grosser mental distortions [than those resulting from grasping onto true existence]. Merely eliminating the gross mental distortions explained in the Abhidharma entails a temporary eradication of active distortions. That is insufficient for becoming an Arhat.

Because those gross distortions are isolated from certain conditions, they do not arise. However, subtle attachment and hostility resulting from subtle grasping onto true existence are not even temporarily suppressed. They are active, and as a result, tainted action is accumulated by that degree of craving and grasping. That power of tainted action is seen both by reasoning and on the basis of scriptural authority.

There are a few people in Burma nowadays who are regarded as Arhats. Now I am not able to gauge their level of realization, but my opinion is that they have temporarily suppressed the active mental distortions that are explained in the Abhidharma. As a result, gross attachment and hostility do not arise, and for that reason they are widely regarded as Arhats. If they have realized subtle emptiness, they could indeed be actual Arhats. If not, they would be Arhats as described in the Abhidharma. But in terms of the [Centrist] system that considers grasping onto true existence as a mental distortion, they would not be Arhats.

46. You may object that as long as craving, which
    clings [to existence] is absent, [liberation] is
    certain. Although that craving is not afflicted
    [by grasping onto an independent self], why could
    it not be similar to confusion?

You [Vaibhashikas] maintain that craving, which grasps onto the aggregates of the body and mind, has been eliminated. However, although craving, as it is described in the Abhidharma, does not appear, the subtle craving that results from grasping onto true existence has not been eliminated. It, too, is a mental affliction.

According to your [Vaibhashika] system there is a twofold classification of confusion: one is a mental distortion and the other is not. Likewise, there is a form of craving that you do not recognize as being a mental distortion.

47. Craving arises from feeling, and feeling is found in those [people you regard as Arhats]. They remain with a mind subject to grasping [onto the true existence] of some things.

If feelings occur in which one grasps onto true existence, craving will arise. Briefly stated: As long as one grasps onto the true existence of objects, the mental distortion of craving will continue to arise.

48. In a mind lacking [realization of] emptiness, the fetters arise again, just as in the case of non-conscious meditative equipoise. Thus, one should meditate on emptiness.

As long as one lacks realization of emptiness, the active arisal of mental distortions, or fetters, may be temporarily suspended; but when the appropriate conditions are eventually encountered, they will arise again. As a result of non-conscious meditative equipoise[22], gross mental distortions temporarily do not manifest; but they recur when contributing circumstances are met. Likewise, as long as one has not eliminated subtle grasping onto true existence [by realizing subtle emptiness], even though gross distortions are temporarily suspended, they will arise again

[22] asaṃjñisamāpatti, 'du shes med pa'i snyoms 'jug

when the appropriate conditions are met. Thus, one should definitely meditate on emptiness.

49. You may say that those utterances that correspond
 to the sutras are acknowledged as the Buddha's
 words. Why then do you not approve of the
 Mahayana, most of which is similar to [your]
 revered sutras?

It is said that the three verses beginning with this one were not composed by Shantideva, for their placing in the text is inappropriate and they denigrate Mahakashyapa.[23] If they did belong in the text, they should appear at the end of the arguments for the authenticity of the Mahayana [i.e. following vs. 44]. In any case, the point of this verse is that since most of the Mahayana sutras are similar to the Hinayana sutras, the former should also be acknowledged as the Buddha's teachings.

50. If the entire [Mahayana canon] is corrupt because
 of one exception, since one [Mahayana] sutra is
 comparable to [the Hinayana canon], why are they
 not all spoken by the Victor?

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[23]None of the verses 49-51 appear in the Sanskrit version edited by P.L. Vaidya (Buddhist Sanskrit Text Series), though they are present in other Sanskrit editions and Tibetan translations.

If one concludes that all the Mahayana sutras are corrupt on the grounds that one of them does not meet the criteria for being Buddha's words, then one could equally claim that all are authentic on the grounds that one of them meets those criteria.

51. This is a doctrine whose depths were not fathomed even by Mahakashyapa. Who then would refuse to accept it simply because you fail to understand it?

In terms of common appearances, Mahakashyapa and others did not fathom the Mahayana sutras. So who would say that they are not to be accepted simply because you do not understand them?

52. [The Bodhisattvas'] presence in the cycle of existence for the sake of those suffering due to confusion is brought about by [their] freedom from attachment and fear. This is the result of [realizing] emptiness.

A person who has realized emptiness does not remain in the cycle of existence due to attachment, or the power of mental distortions and actions conditioned by them. Nor does he [or she] fall to the extreme of seeking annihilation due to fear of the cycle of existence. How can one eternally serve the needs of sentient beings? This, says the author, comes as a result of realizing emptiness.

One needs to integrate the spirit of awakening and the practice of wisdom, viz. the realization of emptiness. In this way, due to wisdom one does not abide in the cycle of existence, and due to compassion one does not abide in tranquility [i.e. Nirvana]. With those two qualities, it is said, it is possible to serve the needs of sentient beings forever. This seems to imply that great compassion is also a fruit of realizing emptiness.

53. Thus, since no refutation can be produced with regard to emptiness, there is no doubt that realization of emptiness is to be cultivated.

54. The antidote to the darkness of afflictive obscurations and cognitive obscurations is [the realization of] emptiness. Why do those [who desire to attain] omniscience not swiftly cultivate it?

55. Let fear appropriately arise toward something that produces suffering; but since [realization

of] emptiness pacifies suffering, why should it be dreaded?

As explained above, grasping onto true existence acts as the basis for the arisal of attachment and hostility. One may fear such grasping, which produces suffering; but it is inappropriate to dread [the realization of] emptiness, which is the antidote for such grasping and which pacifies suffering.

56. If there were some entity called "I," there could be fear due to anything. But if there is no such thing as even the self, whose fear will there be?

If there were an "I" that existed by its own independent nature, then at times of fear one would grasp onto that self, and attachment and hostility would arise. When ordinary people experience fear, there is attachment to the self, thinking, "Poor <u>me</u>!". But if there is no such self, who is there to experience fear?

PART TWO:

IDENTITYLESSNESS

CHAPTER FOUR:

PERSONAL IDENTITYLESSNESS

Refutation of an Intrinsic "I"

Now begins an explanation of personal identitylessness[1]. Up to this point we have presented emptiness as it is discussed in the Centrist treatises. It was shown that this is the most profound theory of emptiness. Idealists assert phenomenal identitylessness[2], but they regard this merely as the absense of external objects. They explain phenomenal identitylessness as follows: "Form does not exist by its own identity as the basis of the concept of form. But such an approach is insufficient for ascertaining subtle emptiness, viz. the lack of intrinsic existence. Thus, the Idealists' way of asserting emptiness is refuted.

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[1]pudgalanairātmya, gang zag gi bdag med

[2]dharmanairātmya, chos kyi bdag med

Then Shantideva argues that the realization of emptiness is indispensable, regardless of one's spiritual "vehicle," be it that of the Listeners, Solitary Sages or Bodhisattvas. Such insight is said to be like the mother of spiritual awakening.

Then in terms of actually meditating on emptiness, the twofold distinction of personal and phenomenal identitylessness is made with regard to the types of entities [whose ultimate nature is emptiness]. There is no difference in subtlety between these two types of emptiness. The discussion of personal identitylessness comes first because emptiness is easier to ascertain with regard to the person [than to other phenomena].

When one says there is no self[3] of a person, the basis of that attribute [of identitylessness] is the person, and the point is that a person has no intrinsic self. In order to ascertain that identitylessness, one must recognize the identity, or self, in question. If its appearance is not

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[3]The Sanskrit ātman, (Tibetan bdag) is here usually translated as "identity," whereas in other Buddhist translations it is often rendered as "self." The Centrist view refutes the existence of two types of ātman, that of persons and that of other entities. The Centrist thus speaks of the lack of an ātman of a table, for instance. In English it is appropriate to speak of analytically seeking the identity of a table, but the notion of a self of a table is peculiar. We may indeed speak of a "table itself," but in reference to a table, we would not normally speak of "its self." Thus, I have usually chosen to use the broader term "identity." The exceptions, as in the above case, occur when the ātman in question is of a personal nature.

clear to the mind, using scripture and reasoning, one will not be able to realize its non-existence.[4]

While dreaming, all kinds of things may come to mind, but these are nothing more than appearances. Likewise, a magician may create a variety of illusory appearances, but they do not exist objectively. Likewise, oneself, others, the cycle of existence, and liberation--in short, all entities--exist merely by the power of mind and convention. In no way do they exist independently from the side of the basis of designation[5]. While actually existing by the power of mind and convention, their mode of appearance is otherwise: Due to our habituation to ignorance since time without beginning, whatever good or bad things that appear to our six types of consciousness[6] do not at all seem to exist by the power of subjective convention. Everything <u>appears</u> to exist from the side of its basis of imputation. That mode of existence that accords with such a deceptive manner of appearance is the subtle object of refutation. Thus, it is to be totally repudiated by means of scripture and reasoning.

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[4] This is similarly true in the investigation of other entities. First one must clearly ascertain the phenomenal nature of the entity in question, and thereafter one can proceed to investigate its ultimate mode of existence.

[5] btags gzhi

[6] The six are the five types of sensory consciousness and mental consciousness.

Whatever good or bad things appear to us seem to exist from the side of those objects. How do they exist? If they exist from the side of the object, then, contemplating the basis of imputation, which lies out there at finger-point, we should see whether it is the object in question or not. Let us take for example a physical object and examine its shape, color and so on to see if that object is to be found anywhere among those attributes. If we do so, we find nothing that is the object in question. If we take a person as an example, and inspect the individual aggregates that are the bases of designation of a person, we find that none of them is the person. In that way we recognize that the imputed object[7] is not to be found upon investigation.

Then if we contemplate how things appear to the mind, we see that they seem to exist from the side of the object, without dependence upon anything else. But when they are sought analytically, they are not found. They do exist, for they can help or harm us. But when pondering the manner in which they exist, we find no basis for the assumption that they exist from the side of the object. Thus, they exist by the power of subjective convention, by the power of designation.

When pondering the nature of existence, we find that entities are not found upon seeking them analytically. So they exist by means of conventional, conceptual designation.

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[7] btags don

They do undeniably exist. But as long as they do not exist independently, from their own side, they must exist by the power of subjective convention. There is no alternative. An entity exists due to its being designated upon something that is not it.

First we need to understand that. Then we should see how things appear to the mind. In this way we should alternate between engaging in the above analysis and inspecting the manner in which events appear. If we integrate these two approaches, eventually whatever appears to the mind will be recognized as seeming to exist not due to convention, but to exist from the side of the object. This mode of appearance, entailing the thing to be refuted, will be clearly ascertained. Then when we apply reasoning to refute the true existence that accords with that mode of appearance, it will be helpful.

Whatever events appear to us now seem to exist from the side of the object, as if there is something out there to which we can point a finger. When we say, "This exists, that exists," pointing a finger here and there, it appears that those things exist from their own side without dependence upon anything else. They seem to exist independently. When we say "identitylessness," the "identity" in question is something existing in that way. The term "intrinsic nature" has the same meaning, as does "independent existence" and "true existence." Since that is non-existent, all entities lack true existence, they do not exist by their own intrinsic nature, or exist independently. They are identityless.[8]

As it says in Nagarjuna's Jewel Garland, there undeniably exists a person, a self, who engages in actions, experiences their results, who is the agent in the cycle of existence and in liberation. There is an "I" that exists in dependence upon the body and mind. If one investigates how the self exists, not being uncritically satisfied with the mere appearance of the self, one looks to the appregates that are the basis upon which it is imputed. One checks whether the person is to be found in the "earth element" [the solid components of the body], the "water element" [the liquid components] and so on. Upon inspection, the self is not in evidence in the elements of earth, water, fire, air or space, or in all of them together. Nowhere among any of the physical constituents is the self identified. Moreover, there is no self that is of a nature distinct from the aggregates; for if there were, it would be unrelated to them. One could not say "my aggregates" [e.g. "my body and mind"].

Yet the self does indeed exist; and its location must be the mental and physical aggregates. It could not exist

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[8]For a helpful table setting forth these terms in a systematic way see Robert A. F. Thurman's translation of Tsong Khapa's Essence of True Eloquence (Princeton Univ. Press, Princeton, N.J., 1984) p. 139.

apart from them. However, not any one of those aggregates, nor the assembly of all of them, nor the continuum that they have in common, nor the individual continuum of any one of them can be identified as being the self.

Some great thinkers, such as Bhavaviveka, identify mental consciousness as the "I." But if one logically analyzes this and applies the word "I" to the mind, this would yield an expression equivalent to "the mind's mind" when saying "my mind." This mistakenly equates the actor and the action. Thus, consciousness cannot be identified as the self. In short, nothing whatever among the four physical elements, space or consciousness is found to be the self. Nothing is so identified by the Awakened Beings or by oneself, nor will the self be found in the future.

Nevertheless, the self exists, and its location could be nowhere but the aggregates of the person. But when those aggregates are individually examined, nothing is identified as the self. Thus, the self can only be something merely conceptually designated upon the mental and physical aggregates. And yet, when it appears to the mind, it does not seem to be a mere conceptual designation upon the aggregates; rather it appears to exist objectively.

57. The teeth, hair and nails are not I, nor am I
    bone, blood, mucus, phlegm, pus or lymph.

58. Bodily oil is not I, nor is sweat, fat or the entrails either. The cavity of the entrails is not I, nor is excrement or urine.

59. Flesh is not I, nor are the sinews, warmth nor air. The bodily cavities are not I, nor is any one of the six types of consciousness.

If the self truly exists in the manner in which it appears, then it should be identifiable as one inspects the components of a person one by one. Following the above verses, no part of the body, including the four elements and space, nor the six types of consciousness can be identified as the self. This implies that the self that experiences joy and sorrow and that appears to the mind as if it existed independently does not exist at all. This is ascertained by engaging in such analysis.

Refutation of the Samkhya Theory of Self

60. If the awareness of sound [were the permanent self], sound would always be apprehended. In the absence of an object of awareness, what, do you say, would be known by what awareness?

In early times there were several non-Buddhist philosophical systems in India, including the Samkhya, Jaina, Vedanta and so on. I do not know if all of them still exist. Among them, the Samkhya system is one of the most profound. Here is a critique of the Samkhya theory of the self.[9]

Centrist: If a person, who is asserted to be awareness, and who experiences sound and so forth, is declared to be permanent [in the sense of being immutable] and partless, the person would have to apprehend sound at all times, even when there is no sound to be heard. Thus, it is incorrect to assert a permanent awareness, for [if there were ever awareness of sound,] it would have to be heard all the time. On the other hand, if there were no object of cognition, in this case sound, what is cognized so that you can even speak of cognition? If nothing is cognized, there can be no cognition.

61. If you assert that awareness exists in the absence
 [of an object of cognition], then it would follow
 that a piece of wood could be awareness. Thus, it

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[9]The Samkhya system asserts that there are an infinite number of selves. The nature of the self is existence and consciousness. It is without parts, and it experiences pleasure and pain. For an extensive introduction to Samkhya philosophy see A History of Indian Philosophy by S. Dasgupta (Cambridge Univ. Press, Cambridge, 1922) Vol. I, Ch. VII.

is certain that without an object of awareness present, there is no awareness.

Centrist: If, even in the absence of sound, the awareness of sound could still exist--implying the existence of awareness with no object--a piece of wood could also be awareness. Thus, there can be no awareness of sound if no sound is present.

62. If that very [awareness] cognizes visual form, why does it not hear sound as well? If you reply that this sound is not nearby, then awareness of that would also not exist.

Centrist: Since awareness of sound is associated with sound, in the absence of the latter, the former cannot be posited. But according to the Samkhya system, a person is awareness and is permanent; thus, if a person ever heard sound, there could be no time when sound was not heard. So when a person cognizes visual form, while there is no sound present, there would also have to be awareness of sound.

Samkhya: In such a case, due to the absence of sound, there would be no awareness of sound.

Centrist: That, however, repudiates your assertion that the awareness of sound has a permanent nature. If it exists at one time and not at another, there is no way to assert that a [permanent] person [identified with that awareness] exists.

63. How can something that is the substance of the apprehending of sound be a cognition of visual form? A single [person] may be regarded as either a father or as a son, but this is not in terms of reality, (only relativistically).

Centrist: It is not possible that something that is the substance of apprehending sound could also be the substance of apprehending visual form. Those two substances could not be the same.

Samkhya: With regard to "perturbation"[10] and "substance,"[11] when a single person apprehends visual form, he lacks the perturbation of sound but still has the substance of sound. So even when he sees form, there is no contradiction in asserting that he is a subject who apprehends sound. This is like regarding the same person as either a father [of his children] or a son [of his father], depending on the perspective.

Centrist: One may designate a single person as a father or as a son, but this is purely a matter of convention. This is not possible if one presumes to speak

[10] vikāra, rnam 'gyur

[11] svabhāva, rang bzhin

of intrinsic reality [as it is defined in the Samkhya or any other system].

64. For neither sattva, rajas nor tamas is either the son or the father. Moreover, the substance of [visual perception] is not seen to entail cognition of sound.

Samkhya: "Sattva"[12] refers to "joy," "rajas"[13] to "suffering," and "tamas"[14] refers to "confusion."[15] These three universal constituents[16] in equilibrium constitute the primal substance of the cosmos[17]. That is the substance[18]

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[12]snying stob

[13]rdul

[14]mun pa

[15]For an explanation of these three constituents see S. Dasgupta's <u>A History of Indian Philosophy</u>, Vol. I, pp.243-247. Dasgupta translates <u>sattva</u>, <u>rajas</u> and <u>tamas</u> respectively as "intelligence-stuff," "energy-stuff" and "mass-stuff." He comments (p. 245) that "in the phenomenal product whatever energy there is is due to the element of rajas and rajas alone; all matter, resistance, stability, is due to tamas, and all conscious manifestation to sattva."

[16]guṇa, yon tan

[17]prakṛti, gtso bo. When the Samkhyas speak of a pervasive primal substance whose perturbations result in the manifold world of natural phenomena, we may be reminded of speculations in modern physics concerning the role of the vacuum in the cosmos. As mentioned in the closing paragraphs of Chapter One of Book I, some physicists believe that the entire universe originated from a fluctuation of the energy of the vacuum. Further, as we examined in some detail, it may be that this energy is infinite. However, significant differences are present. Astronomer E. R. Harrison claims that the original state of the universe was one

of phenomena, and it is regarded as ultimate truth.[19] This ultimate substance is never seen in the world of phenomena, and phenomena that are seen are regarded as illusion-like and deceptive. Thus, the primal substance in the case of the son is not the son, nor in the case of the father is it the father.[20]

Moreover, the substance of the cognition of visual form is not seen to be the substance of the cognition of sound, i.e. they are not seen to be identical.

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of irrational, indeterministic chaos. On the other hand, P. T. Raju writes [The Philosophical Traditions of India, (George Allen & Unwin Ltd, London, 1971) p. 161.] that the primal substance of Samkhya cosmology "is not a chaotic stuff, but something in which everything is in harmony and equilibrium. We cannot attribute order to it, because the concept of order implies plurality among the members of which definite, fixed relations exist. Prakrti is originally absolute equilibrium, but completely undifferentiated."

[18]svabhāva, rang bzhin. This term is often translated as "nature." However, when used in the context of ekasvabhava, the translation "substantially identical" seems most fitting; hence the present translation.

[19]cf. A History of Indian Philosophy, Vol. I, pp. 245-248.

[20]While the Samkhya philosophy asserts the existence of a plurality of selves, it fundamentally treats the material world as a unity, namely the primal substance. This unity appears in a plurality of forms, and even time and space have no separate existence. It appears in the same way for every self, and it is independent of any self. Although it is not sentient, mind is one of its products; thus, it is the original stuff of the psycho-physical world. On the relationship between the self and the primal substance P. T. Raju comments: "The original distinction, for the Samkhya, is not between mind and matter, but between the ātman, which is infinite consciousness, but indeterminate and Prakrti, which is the infinite unconscious, but determinate. It is out of this infinite, but determinate unconscious that the manifold world evolves." (The Philosophical Traditions of India, pp. 160-161).

65. But if [the cognition of visual form is the cognition of sound] in another form, like an actor, then it is not permanent. If [the cognition of form] is another cognition, then that singularity is unprecedented.

Centrist: If one substance takes on different forms, then it is incorrect to say that it is permanent [in the sense of "unchanging"]. A permanent substance that is identical with something whose form changes is unprecedented. There could not be a truly existent substance that takes a variety of forms. Such an entity would have to be unreal.

66. If you claim that the other mode [of cognition] does not truly exist, then say what its natural form is. If you reply, "Consciousness itself," then it entails the [unwanted] consequence that all conscious beings are identical.

Centrist: If you say that another mode [of a certain cognition] does not truly exist in the manner in which it appears, but exists as a single substance, tell us what that intrinsic nature, or substance, is. If you claim that consciousness itself is truly existent, then it would follow that all beings are one. Since all beings with different continua would have such a nature, it would follow that they would all be identical.

67. That which has volition and that which lacks it would be the same, because their very being is equivalent. If a specific entity is deceptive, what corresponding basis does it have?

Centrist: If multiple entities are alike in all respects due to a single similarity, then things that have and do not have volition would be the same, for they are alike in their very being[21]. If specific, distinct perturbations, such as visual cognition and audial cognition, are false, or deceptive, since they are similar, what is their corresponding, truly existent primal substance?

Refutation of the Nyaya Theory of the Self

68. That which is not conscious is not I, because it lacks consciousness, just like a cloth and so on. If you counter that it is conscious since it is

[21] astitā, yod pa nyid

conjoined with consciousness, then it would follow that the non-conscious entity would vanish.

Naiyayika: We deny the existence of a self that is of the nature of awareness. Rather, in a person's being there is an immutable, partless, pervasive material entity that lacks volition but nevertheless experiences the world and engages in action. That entity is the self.[22]

Centrist: An unconscious material substance is not an experiencing self because it lacks consciousness, just like a pot and so on.

Naiyayika: Although the self is an unconscious material entity, since it is endowed with consciousness, it is aware of things.

Centrist: Then when that consciousness becomes of the nature of the self, the previously unconscious self would change. In that case it could not be immutable.

69. Moreover, if the self is not subject to change, then what is the use of its consciousness? Thus, lacking consciousness and being separate from activity, space could be regarded as the self.

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[22]For an extensive introduction to the Nyaya-Vaisheshika philosophy see S. Dasgupta's A History of Indian Philosophy, Vol. I, Ch. VIII.

Centrist: If the self is immutable, partless and pervasive, what effect could consciousness have on that material entity? Moreover, since you assert that the self is of a material nature, devoid of consciousness and divorced from activity, you may as well declare that space is the self.

Rebuttal of Arguments Against Identitylessness

70. One might say that in the absence of a self there
would be no proper relationship between an action
and its result. If the agent vanishes upon having
performed an action, who will [experience] this
result?

The author previously argues that there does not exist a self that conforms to the way it is conceived when we grasp onto true existence. He then repudiates the speculative, non-Buddhist concept of the self as being permanent, partless and independent.[23] Now he presents an objection to the Centrist theory of the self.

Objection: If the self does not exist, then there is no way to assert any relationship between action and its result. Why? Because the time of engaging in an action and

[23] This concept of the self is common to most Indian philosophies.

the time of experiencing its result are distinct. If one has committed a deed as a human being, it is possible to experience its results later in a non-human existence. Thus, if a self who has the same being is not acknowledged for those two existences, since they have different bodies and different minds [which are dependent on each body], there would be no relation between an action and its fruition.

The composite of the body and mind at the time of performing an action vanishes. When the effect of that action is experienced, another composite of body and mind has formed. So when the fruition of the act is experienced, whose fruition is it?

71. Since we both agree that an action and its fruition have different bases, and that the self who performs the action does not function at the time [of its fruition], is it not pointless to dispute this issue?

Response: The person at the time of performing an act and the person at the time of experiencing its result exist at different times and are of different natures. We both agree on this point. Neither of us believes that the self that experiences the effect is the self that engaged in the action. So there is no point in debating this issue.

72. It is not possible that the very possessor of the cause can be seen to be "endowed with the effect." Rather, agent and experience are designated depending on their oneness of continuum.

At the very time that a cause is created it is impossible for there to be an experience of the effect of that cause. The "self" is designated upon a continuum of consciousness. In this way one can say, "In a previous life I committed an action, and now I am experiencing its result."

The self that existed yesterday and the self today are different. Yesterday's self has passed, and today's self has newly arisen, but they are of the same continuum. Thus it is correct to say, "Today I experience the results of what I did yesterday."

73. The past or future mind is not the "I," for it is not found. Moreover, the present mind is not the self; [for if it were,] upon its passing, the self, too, would not exist.

If the self is designated upon the continuum of consciousness, one might well ask if consciousness itself is the self. The answer is in the negative. The past and future mind is not the self because it does not exist. When speaking of the past, future and present, the past has ceased and the future is yet to come. Roughly speaking, i.e. in terms of convention, it is possible to talk of the three times. But more precisely, if one distinguishes the past and future with regard to individual earlier and later moments, the former belong to the past and the latter to the future. The present is not to be found.[24] Thus, the present mind is not the self, for as soon as it had passed, the self would become non-existent.

74. When the trunk of a banana tree is cut into pieces, there is nothing left over. Just so, the "I" is not [found to be] really existent, when sought after analytically.

As it says in the Jewel Garland, if one cuts apart the trunk of a banana tree, which has no core, it is found to have no essence. Likewise, if one seeks the self, no entity can be found that is the self.

75. You might ask: If no sentient being is found, towards whom would one feel compassion? For

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[24] Like a point on a line, it disappears when precisely sought.

practical purposes [one feels compassion for beings] who are imputed by acknowledged delusion.

Objection: Now when one seeks the designated object, the self is not to be found. The terms "self," "person" and "individual" are equivalent, and the entity so designated is not to be identified. One cultivates compassion by reflecting, "People wish to be free of suffering, yet they are in pain. Might they be free of misery!" But if the person for whom one feels compassion is not to be found, to whom is the compassion directed?

Response: As it states in the Jewel Garland, due to ignorance as the cause, tainted actions are performed and beneficial and detrimental results follow. That ignorance is not to be denied, for it yields both benefit and harm. Sentient beings are not identifiable by analysis, but without such examination they evidently engage in actions and experience their pleasant and painful results. One must acknowledge the explanation of the effects that ensue from ignorance. However, one does not assert them as truly [ie. intrinsically] existent. They exist merely by the force of convention, without examination or analysis. The "delusion" that is referred to above does not refer to grasping onto true existence. Rather, it refers to delusion as it is popularly conceived, entailing no examination or analysis.

There do exist sentient beings, who give help and inflict pain. When saying that they exist only conventionally, the meaning is that they are not found under analysis; so they do not ultimately, or truly, exist. That which does exist does so by the force of convention, as a name; and it is deceptive, like an illusion. Its existence is established by deceptive but nevertheless verifying cognition[25].

There is no way to establish the existence of anything unless one refrains from [ultimate] examination and analysis. However, it is necessary to draw a distinction between a person who appears in a dream and one who is encountered when one is awake. They are similar insofar as both are not truly existent. But if the former is designated as a person, this is repudiated by other conventional cognitions. If the latter is designated as a person, this is not contradicted by such cognitions, nor is

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[25]'khrul pa'i tshad ma. A verifying cognition must be unmistaken with respect to its chief object ('jug yul), viz. the main object that it ascertains. However, it may at the same time be a deceptive cognition with respect to its appearing object (snang yul). For example, a verifying inferential cognition correctly ascertains the inferred object. But since that object and the idea of that object appear to such cognition as if they were fused together, this cognition is deceptive wither respect to that appearance. Why? Because the object and the idea of it do not exist in the manner in which they so appear. According to the Centrist view, a perceptual verifying cognition can also be deceptive with respect to its appearing object. That object appears to be truly existent, but in fact it is not.

it repudiated by ultimate analysis. Thus, such a being exists conventionally as a person.

If something is not repudiated by other conventional cognitions, nor by ultimate analysis, it may be asserted to exist. But there is nothing that exists on its own. There is no such mode of existence.

76. You may ask: If there is no sentient being, whose
is the goal? We grant that such desire [for
liberation, etc.] is indeed delusive. Still, in
order to eradicate suffering, effective delusion,
whose result [is understanding of the ultimate] is
not prevented.

Objection: If sentient beings do not exist, who is it that attains the fruition of the spiritual path--full awakening? And while on the path, for whom does one cultivate compassion?

Response: Sentient beings do exist. It is for them that compassion is felt, and compassion is cultivated by existent people. Whatever is designated by delusion [as it was described above] is to be acknowledged. Due to cultivating compassion while on the spiritual path, the fruition of full awakening is attained. Who attains awakening? That, too, is to be established conventionally, without [ultimate] examination or analysis. In order to pacify the suffering of oneself and others, impure appearances that arise due to ignorance are not to be rejected.

77. Grasping onto the "I," which is a cause of suffering, is strengthened due to delusion about the self. You may think that you cannot get rid of it, [but for this,] meditation on selflessness is ideal.

The mental affliction of grasping onto the "I" is a cause of suffering.[26] One may doubt that there is any way to overcome that affliction; but it is indeed possible, and for this, meditation on identitylessness is ideal.

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[26] In this verse the Sanskrit <u>ahaṃkāra</u> (grasping onto the "I") reads in the Tibetan translation as <u>nga rgyal</u>.

CHAPTER FIVE:

PHENOMENAL IDENTITYLESSNESS

The Four Applications of Mindfulness

Mindfulness of the body

In the explanation of phenomenal identitylessness, the author discusses the four applications of mindfulness[1] on (1) the body, (2) the feelings, (3) the mind and (4) other phenomena. Those four subjects are brought under examination and are established as not truly existent. Thus, the conventional nature of those four is not investigated; rather, mindfulness is applied to their ultimate mode of existence.

78. The body is not the feet, the calves, nor the thighs; nor is it the hips, the abdomen, the back, the chest or the arms.

79. It is not the hands, the sides of the torso, the armpits or the shoulders; nor is the neck or head the body. So what here is the body?

[1] smṛtyupasthāna, dran pa nye bar gzhag pa

If the self is imputed in dependence upon the body and mind, what then is the nature of the body? We say "my body" and "human body," and such designations are made upon the collection of the feet, head, hands and so on. If one asks whether any individual component such as the head or a hand is the body, the answer must be "no." For if each part were the body, then a person would have many bodies. If quite a few of the parts are missing, it seems that there is not a body, but if only one is missing, the body still seems to be there. This is a matter of convention. If it seems inappropriate to make the designation of "body," it appears that there is no body; but if the designation is made, then there is a body. This is not determined by some presumably objective reality.

In terms of the author's analysis, the feet and so on are the parts, and a single human body is that which has those components. The "whole," the body, is imputed in dependence upon its parts. None of those parts can be identified as being the body.

80. If this body occurs partially in all [of the parts], and the parts occur in [all] the parts, where then can this [body as a whole] stand itself?

Hypothesis: The body, as the whole, is distinct from its individual parts, and it pervades all of them part by part.

Response: You may assert that the body as the whole exists in each of its components, but this suggests that the body itself is not composed of parts. Where then does it exist?

81. If the body were itself wholly located everywhere
among the hands and so on, there would be just as
many bodies as there are hands, etc.

If the whole body were located in each of the parts, there would be as many whole bodies as there are parts of the body, including the hands and so forth.

82. As the body does not [intrinsically] exist in the
interior or on the exterior [of its parts], how
can it exist among the hands and so on? As it is
not distinct from [each of its parts, including]
the hands, etc., how can it exist at all?

When one seeks the imputed object, the body itself is not found either inside or on the surface of the parts. Since no independent, truly existent body is found, how can it exist among those parts? As the body is not of a different nature from its parts, then that designated object is not to be found.

83. While the body does not [intrinsically] exist, due to delusion there occurs a cognition of [an intrinsically existent] body among the hands and so on. This is like apprehending a pillar as being a person due to a certain configuration.

Thus, although there is no intrinsically existent body, on the basis of the components, including the hands and so on, a self-defining body appears to the mind. This is like looking on a pillar in the shape of a human and mistaking it for a human.

84. As long as there is the complex of conditions, the body [appears] as if it were a man. Likewise, as long as the hands and so on are present, the body is seen there.

On the basis of the assembly of the parts of the body one says "my body," "a good body" and "a poor body." In such cases the body seems clearly to exist from its own side. In fact the body is no more than a name which is designated on a certain basis, but it seems quite different from that.

85. Likewise, what would a hand be, [other] than an assemblage of fingers, or a [finger other] than a configuration of joints, or a joint [other than] its own separate parts?[2]

Previously there was an analysis of the body as a whole, and now the author discusses its components [e.g. the hands], the parts of those components [e.g. the fingers] and so on. "Hand" is imputed upon the configuration of the fingers, the palm and so on, but the hand does not exist among those individual parts. And there is no hand existing independently of those separate parts. Likewise, "finger" is designated upon a configuration of joints, and the joints, too, have their own separate parts.

86. Those parts, too, [exist only] due to the different atoms, and even the atoms [exist only] due to the divisions of their directional facets. Since those directional facets have no [intrinsic] parts, they are [like] space. Thus, the atom does not [intrinsically] exist.

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[2]The Tibetan reads "hand" and "fingers," whereas the present version of the Sanskrit reads "foot" and "toes or fingers" (aṃguli means either, depending on the context). The Tibetan version seems to be a slightly more likely reading.

87. What discerning person would be attached to form, which is thus like a dream? Therefore, if the body does not [truly] exist, who is a [real] man and who a [real] woman?

Thus, it is inappropriate for an intelligent person to be attached to form, which is dream-like. The terms "man" and "woman" are designated on the basis of the differences between male and female bodies. Since the bodies that are the bases of those imputations are not found under analysis, how could a man or woman intrinsically exist?

Mindfulness of the feelings

88. If suffering exists in reality, why does it not prevent joyful experiences? If happiness [truly] exists, why do savory things and so on not brighten up the pain of grief and so on?

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we have seen in Book I, the ability of a theory to yield predictions that are empirically verified is no guarantee of its validity. If the vacuum does in fact bear a structure and energy, those entities should be directly experiencable by the human mind. If there is no possible way of experiencing them with verifying perceptual cognition, Buddhism does not admit to their existence.

If the feelings[6] that we experience existed independently [i.e. truly existed], they would not depend on other circumstances. If that is the case, why does suffering not prevent joy? A person who experienced suffering could never feel happy. Moreover, if happiness is a self-defining entity, then on occasions of grief and so on, why do not sensual sources of pleasure [e.g. food and drink] bring one happiness?

89. You may say [such pleasure] is not experienced due
to its being overridden by intense [suffering].
How then can something that is not experienced be
a feeling?

Hypothesis: At times of grief there may be pleasure as well, but it is overridden by the more intense misery.

Response: Feeling is by definition of the nature of experience. So if something is not experienced, the term "feeling" cannot be applied to it.

90. You may maintain that there is subtle unhappiness
[when there is great delight]; and while gross
misery is removed, you may believe that [subtle

[6]The term "feeling" (vedanā, tshor ba) as it is used here has a more limited meaning than is usual in English. It refers to physical and mental feelings of pleasure, pain and indifference. It does not include, for instance, the tactile sensation that arises when one touches an object.

discontent] is simply another pleasure. If that were the case, then even that subtle [satisfaction] would be [joy].

Hypothesis: When intense joy arises, if there is subtle dissatisfaction, what feeling does that joy displace, that allows it to be called "intense joy"? Does it not displace gross unhappiness? It removes gross misery, but subtle discontent remains. So that misery is not unexperienced; it is simply subtle. Moreover, that subtle dissatisfaction is actually a subtle form of pleasure, distinct from the intense joy.

Response: Since that subtle form of pleasure is a type of happiness, it cannot be classified as suffering. Even subtle pleasure is a form of happiness.

91. If you hold that suffering is not produced upon the arisal of incompatible conditions, does this not imply that a "feeling" is a conceptual designation?

Hypothesis: When there is the experience of intense joy, which is incompatible with suffering, the latter is not produced.

Response: In this case you err in conceiving of feeling as being self-defining. The feelings of joy and sorrow do not exist from their own side. While they exist as conceptual imputations, you cling to them as existing from their own side. Feelings do not exist by their own intrinsic nature; rather, they are identified on the basis of contributing circumstances.

92. Therefore, this analysis is cultivated as an antidote for that [false conception of intrinsic existence]. The meditative absorption that arises from the field of discriminative investigation is the food of the contemplative.

Feelings do not truly exist; they are not found when sought through analysis; they do not exist independently, but exist by the power of convention. Thus, the means for overcoming the misconception of the true existence of feelings is meditation on their lack of such existence. This entails analyzing the mode of existence of feelings.

Such investigation is an aid to meditative absorption and leads to the integration of meditative quiescence and insight. That increases the physical vitality of the contemplative[7] and enhances the power of his [or her] spiritual practice. Thus it is called the nourishment of the contemplative.

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[7] yogin, rnal 'byor pa

93. If there is an interval of space between the sense organs and sensory objects, where is the contact between the two? If there were no interval, they would become one; in which case, what could contact what?

Now the author refutes the true existence of feelings. We speak of feelings as being conditioned by contact with an object. An object is experienced by means of the combined interaction of the object, the sensory organ and consciousness. By that process feelings arise. So here the author analyzes contact to see whether it is truly existent or not.

If there is a spatial interval between the material particles that make up a sensory organ and those of the sensed object, where does the contact between them take place? If there were no such interval between the elementary particles of the sense organ and the object, they would indivisibly occupy the same space. In that case they would become one. If particles had exactly the same location, they would not be distinct, so one could not speak of any contact between them.[8]

[8]Recall that in modern quantum field theory the concept of individual elementary particles remains very problematic. Moreover, as noted in Chapter 13 of Book I, there is considerable disagreement among contemporary physicists concerning the actual nature of atoms. Physicist d'Espagnat claims that they are mere properties of space; Stapp argues that they are a set of relationships; and Heisenberg denies that they are things. The

94. There is no interpenetration of two atoms, for there is no empty space [in them] and they are of the same size. If there is no penetration, no intermingling occurs; and if there is no intermingling, there is no contact between them.

One cannot speak of any interpenetration of atoms, since atoms contain no empty space and are of the same dimensions.[9] Moreover, if atoms do not penetrate one

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Centrist theory does not deny the existence of atoms; but it does refute the assumption that they exist as real entities independent of conceptual designation.

[9]This statement would be contested by most contemporary physicists, citing the work of Rutherford in 1911., who experimentally demonstrated that most of the interior of an atom is composed of empty space. This idea is closely related to the "planetary model" of the atom, in which the electrons orbit about the nucleus. Now modern quantum theory, with its wave/particle duality and uncertainty principle, states that this model is misleadingly simplistic. Furthermore, the mysterious nature of the presumably empty space within the atom has already been discussed at length, with the conclusion that "empty space" seems to be far from empty. However, in the context of this Buddhist text, it is more important to recognize that the Buddhist concept of atoms differs radically from that of modern Western science. Buddhist contemplatives have used their own heightened powers of awareness, developed through rigorous training in meditation, as their means of exploring the smallest components of the physical world. Modern physicists use mechanical instruments and mathematics in formulating their atomic theories. Recall Heisenberg's comment, cited in Chapter 14 of Book I: "What we observe is not nature in itself but nature exposed to our method of questioning." Given these two radically different methods of questioning, it is hardly surprising that the resultant theories differ as much as they do.

another, there could be no intermingling of them, and thus there would be no contact among them.[10]

95. If they are partless, how is contact between them ever supposed to be justified? If contact between partless particles has been observed, please demonstrate it.

If at the subtlest level there is no space between atoms, they would be identical. If there is actual contact between atoms and if there is contact between them without their having any parts or attributes, this should be demonstrated.[11]

96. Contact [by atoms] with immaterial consciousness is implausible; nor [is there contact among the

[10]Once again, this statement must be understood within the context of Buddhist atomic theory. It would be inappropriate to equate the Buddhist usage of the term "atom" with that of modern physics. Having emphasized this point, it may be of interest to note that modern physics is far from certain as to the manner in which particles of matter do interact. Are they interconnected by a system of fields, or is Schwinger's "source theory," which dispenses with fields, truer of physical reality? The Einstein-Podolsky-Rosen Paradox and Bell's Theorem discussed briefly at the end of Chapter 17, Book I also pertain to such questions.

[11]Once again we encounter the Buddhist insistence upon verifiable, experiential confirmation of theory. Merely having a theory that "saves the appearances" is insufficient; for multiple, conceptually incomptible theories may equally save the same set of appearances. If one professes a theory in which atoms come into actual contact, or in which they have no components, one should be able to demonstrate the means by which one has gained direct, experiential verification of that theory.

atoms involved] in the conjunction [of sense organ and object], since they are not real, etc.

Here is an analysis of consciousness. The theory under inspection posits the arisal of cognition conditioned by (1) the sensed object as the objective condition[12], (2) the sense organ as the dominant condition[13], and (3) the preceding instant of consciousness as the immediate condition[14].[15] Since the third condition, consciousness, is immaterial, one cannot say that there is contact with it.[16]

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[12] ālambanapratyaya, dmigs rkyen

[13] adhipatipratyaya, bdag rkyen

[14] samanantarapratyaya, de ma thag rkyen

[15] See The Mind and its Functions by Geshé Rabten, trans. by Stephen Batchelor (Tharpa Choeling, 1801 Mt. Pelerin, Switz).

[16] Buddhism does clearly make a distinction between mind and matter, or between cognitive and physical events. Cognitive events, such as sensory awareness, memory and imagination, experience their respective objects. Physical entities, acting as objective conditions and dominant conditions, may certainly contribute to the arisal of various forms of cognition; but they themselves experience nothing. Thus, the eye mechanism and physical processes in the brain are obviously involved in the experience of vision; but Buddhism finds it preposterous to equate those physical events with visual perception itself. Although there is abundant evidence for believing that certain neurophysiological processes are necessary for normal visual perception to occur, what scientific grounds are there for equating the two? Materialists may suppose that perception is nothing more than a physical process, but who has ever experientially verified this theory? Now the Centrist view acknowledges the role of the three types of conditions mentioned in the commentary, but it denies that any such interactions have real, intrinsic existence. Moreover, the causal interactions between physical and cognitive events go both ways: Subjectively experienced cognitive processes affect physical processes, as do physical influence the cognitive.

Moreover, there can be no true contact with a macroscopic collection of particles, for such a collection does not truly exist. This point was analyzed previously in the discussion of the parts of the body.[17]

97. Thus, if contact is not [truly] existent, how is feeling possible? What is the point of exertion? Who could be harmed by what?

For contact to take place, there must be the "contacter" and the "contacted." But if one seeks those imputed objects among the sensory object, sense organ and consciousness, no truly existent objects are found. Thus, contact does not intrinsically exist. Feeling arises in dependence upon contact, and if the cause does not truly exist, neither does the effect. Thus, contact does not intrinsically exist. Feeling arises in dependence upon contact, and if the cause does not truly exist, neither does the effect. So, whence could truly existent feelings arise?

Desiring to experience pleasant feelings and to avoid unpleasant feelings, people exert great effort towards those ends. But what is the point? What unpleasant feeling could harm what person? If one seeks the imputed object, one finds no harmful feeling nor any harmed owner of that feeling.

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[17]cf. verse 85.

98. If any [truly existent] experiencer [of feeling] or [truly existent] feeling is not found, and one has recognized this situation, why do you not turn away from craving?

When a contemplative applies Centrist analysis in search of imputed objects, he [or she] discovers that no experienced object or experiencing self is to be found. In the face of such analysis, no feelings or experiencer of feelings exists. If one refrains from investigation and analysis, one can speak of an experiencer of feelings since one is endowed with the function of feeling; and one can speak of feelings, since they are experienced. That is valid in a purely conventional sense.

But in a true, objective sense, if one were to speak of an experiencer who has the function of feeling, one would be dealing with two entities: (1) the person who experiences and (2) apart from that, the experience itself. Then, as explained in Nagarjuna's Fundamental Wisdom, if the two are separate, there could be action without the agent of the action, and an agent unrelated to any action. That is impossible. Or [if one denies that they are separate, then] the action that enables us to speak of an agent would be identical with that agent. That, too, is a fallacy.

One discovers that no intrinsically existent feeling or experiencer is to be found. Now the mental affliction of craving arises due to mistakenly grasping onto the independent existence of objects. Thus, the confusion of grasping onto true existence is the basis of attachment and hostility. Once one has ascertained the non-existence of the object of such delusion, craving vanishes.

Subtle attachment and hostility are conjoined with the confusion of subtly grasping onto true existence. That conjunction is difficult to understand. For the most part, Buddhist philosophical systems from the Svatantrika on down claim that such cognition is objectively appropriate[18]. In fact, they seem to assert as appropriate the mere awareness of a pleasant object as being pleasant. So, while the Prasangika system regards as a mental affliction the subtle grasping onto true existence, which lies at the root of attachment and hostility, Buddhist systems from the Svatantrika down to the Vaibhashika seem to maintain that such grasping is appropriate.

Now gross attachment and hostility resulting from the mistaken sense of a self-sufficient, substantial personal identity fundamentally arise from grasping onto true existence. If, using logical analysis, one refutes the object of such grasping, such that grasping onto true

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[18]don mthun

existence does not arise, then the mental distortions that are produced by that confusion are averted.

As Chandrakirti states in his Clear Words[19], that which acts as an antidote to confusion acts as an antidote to all mental distortions. On the contrary, specific antidotes to attachment, anger and pride do not remedy all distortions. But the antidote to the confusion of grasping onto true existence acts as a remedy for all mental afflictions.

99. That which is seen and that which is touched are of a dream-like and illusion-like nature. Because feeling arises together with the mind, it is not [ultimately] perceived.

There is nothing whatever that has a true mode of existence. Nevertheless, this does not suggest that a person who experiences feelings and the feelings themselves--pleasant and unpleasant--are utterly non-existent. They do exist, but in an untrue fashion. Thus, the things that we see and touch have a dream-like and illusion-like quality.

In the second line the author refutes the true existence of the mind that experiences feelings. Since feelings arise in conjunction with the mind, feelings are not perceived by the mind that is simultaneous with them. There must be a causal relationship between the experienced

[19] Prasannapadā, Tshig gsal

object and the experiencing subject. If two entities are substantially distinct and exist simultaneously, there could be neither a causal relationship nor an identity relationship[20] between them.

For this reason the author denies that either [intrinsic] relationship could hold for the feelings and the awareness that is simultaneous with them. Two mental events that arise in conjunction with each other are not able to apprehend one another. This holds true for all states of awareness. Thus, feelings are not observed by the awareness that arises in conjunction with them and that exists simultaneously with them.

100. With two events arising sequentially, [the former] may be recalled but not experienced [by the latter]. Feeling does not experience its own nature, nor is it [truly] experienced by anything else.

A feeling is not observed by an awareness that exists prior to it, nor is it seen by a later cognition that exists after the feeling has ceased. It is incorrect to say that something observes itself, as this was established in the

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[20] bdag gcig 'brel. An identity relationship is present when distinct entities exist simultaneously and are of the same nature. For example, the red color of an apple bears an identity relationship with the apple.

refutation of self-cognition. If one posits that one thing is experienced by something else [that is intrinsically different], this results in infinite regress.[21] Thus, in terms of true existence, experience cannot be posited at all.

101. There is not any [intrinsic] experiencer [of a feeling], and in reality there is no feeling. It being the case that this composite is identityless, who then is hurt by this [kind of unreal feeling]?

Since the experiencer of a feeling does not truly exist, feeling also does not exist in reality. So what harm can be inflicted upon this aggregate that is devoid of an identity or intrinsic nature?

While the psycho-physical aggregates of a person lack an intrinsic identity or self, we fail to recognize this and mistakenly become attached to those aggregates. But if we analytically seek the imputed object [the self], that fallacy is dispelled. How then could that [non-existent, intrinsic self] be harmed?

Grasping onto true existence is what makes us vulnerable to harm. Since there is no basis for such

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[21] cf. verse 22.

grasping, how can harm be inflicted [upon that non-existent basis]?

Mindfulness of the Mind

102. Mentality is not located among the sense organs, nor in form and so so, nor in between them. The mind is also not found inside [the person], nor outside, nor anywhere else.

Awareness is not located among the sense organs, nor among the outer sensory objects such as visual form, nor in between them. Some non-Buddhists believe that awareness exists in the interior of a person, while others think that it exists in the extremities of the body such as the hands.[22] But the mind does not exist in either of those places, nor is it found elsewhere.

103. It is not [truly] in the body, nor somewhere else; it is not [truly] mixed [with the body] nor is it

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[22]There is a common belief nowadays that visual perceptions, thoughts and mental images are located in the brain. That the brain is involved in the arisal of these cognitive events is undeniable and is hardly a recent discovery. But where is the evidence that these subjectively experienced events occur in the head or anywhere in physical space? For a critique of this assumption by a Western philosopher, see E. A. Burtt's The Metaphysical Foundations of Modern Physical Science, Chapter 8, (b).

anywhere apart. It is not [truly] anything at all ,so sentient beings are fully liberated.

The mind does not intrinsically exist in the nature of the body, nor elsewhere, nor as a mixture with the body, nor on its own apart from the body. If the imputed object, the mind, is sought, one discovers that it does not exist independently. Thus, sentient beings are by nature liberated.

The foregoing discussion concerns mental awareness. Now the author goes on to analyze sensory awareness.

104. If awareness exists prior to the object of awareness, perceiving what, does it arise? If awareness is simultaneous with the object of awareness, perceiving what, does it arise?

If sensory perceptions, such as visual awareness, exist prior to their respective objects, in dependence upon what do they arise? Visual awareness, for example, has to arise in dependence upon form as the objective condition for its occurrence. So if visual awareness precedes its object, in dependence upon what does it occur.?[23]

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[23]This verse makes it quite clear that the Centrist view avoids not only the extreme of materialism but of idealism as well. Physical phenomena do indeed depend for their existence upon mental designation, but perceptions of the physical world, such as visual cognition, require for their arisal objective

If awareness and its object arise simultaneously, the same problem arises; for something that acts as the objective condition for the arisal of a cognition must precede that cognition. Causal relationships are necessarily sequential.[24]

105a. Moreover, were it to occur after its object, whence would awareness [truly] arise?

If awareness arises after its object has ceased, in dependence upon what would that awareness occur?

Mindfulness of Phenomena

105b. Thus, the [intrinsic] arisal of all things is not ascertained.

Thus, when seeking the imputed object in terms of any entity whatever, one discovers that everything lacks

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conditions. The Centrist view does acknowledge a dualism between cognitive and physical events, but the two are seen as mutually interdependent. Moreover, the dualism itself has purely a conventional status; it, too, exists in dependence upon conceptual imputation.

[24] Although causal relationships are sequential, cause and effect are not separated by absolute, objective time. According to the Centrist view, not only are effects dependent upon their causes, but causes depend upon their effects.

independent existence. Everything exists in a relational way, purely by the power of convention.

Refutation of Objections

106. If that is so, conventional truth does not exist; so how could there be the two truths? On the other hand, because of another being's conventional truth, [conventional reality remains after one's own imaginative construction ceases]. If that is so, how is a being ever liberated?

Objection: You Centrists claim that no imputed object is found under analysis, and that emptiness itself does not exist. Upon seeking imputed objects, you conclude that there is no form, sound, smell, taste, tactile object nor mental object, and that there is no truth of suffering, truth of the source of suffering, truth of cessation or truth of the path. You say that everything does not exist.

You seem to maintain that all conventional realities that are involved in causal relationships are mere apparitions appearing to deluded minds, since they have no intrinsic existence. But if they are not intrinsically existent, they do not exist at all. In that case, how can there be the two truths? Ultimate truth would be out of the question, for it must be established on the basis of something that exists. But if that basis does not exist, it has no ultimate nature. Thus, relative and ultimate truth could not be posited.

If, according to you, everything that is posited consists purely of apparitions appearing to confused minds, then Nirvana would be impossible. Indeed, worldly judgements of "good" and "bad" would not hold up. Moreover, a cosmic primal substance, God, the Three Jewels of the Buddha, Dharma and Sangha[25] would all have the same status: If one of them exists, they all exist. For a confused mind such a primal substance may exist, God may exist, the horns of a rabbit may also exist. To a mind that conceives of rabbit horns, they exist. In short, if you say that something exists simply because it seems to be real to a deluded mind, nothing could be denied existence.

In that case "true" and "untrue," "good" and "evil," conventionally "existent" and "non-existent" all lose their meanings. One could no longer speak of false views, such as denying something which does exist and asserting something which does not exist. Thus, by undermining the distinction between "good" and "evil," there could be no liberation by means of correctly avoiding evil and adopting virtue. Moreover, liberation itself would be nothing more than an apparition of a deluded mind.

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[25]For an explanation of the Three Jewels see Tibetan Tradition of Mental Development, pp. 60-69.

107. That construct [of one's liberation] in another's mind [would reify one's ultimate liberation; but it does not emerge] from one's own conventional reality. [And another's delusion cannot make something conventionally real, since] if something is [relatively] determined after [realizing emptiness], it [conventionally] exists; if not, it is not [even] a conventional reality.

The objection that if something is said to exist merely because it is conceived by a deluded mind that grasps to true existence, it would not be able to render help nor inflict harm. It would simply be an illusion.

Response: One cannot claim that something exists simply because it is conceived by a deluded mind.[26] So according to our [Centrist] system, that is not the

[26]Here the fallacy of extreme relativism is avoided. Although entities exist in dependence upon conceptual designation, it is not true that one person's concepts are necessarily as valid as another's; nor is it true that each person lives in his or her own reality determined solely by that individual's beliefs. For example, one who is convinced that death entails complete personal annihilation is not extinguished at death simply because of that mistaken view. We may deny things that do exist; and though we are influenced by such false views, we do not escape influence by the things that we deny. Similarly, we may believe in things that do not exist. We are then influenced by such false beliefs, but not by the non-entities that we believe in. The central purpose of Buddhist mental training is to recognize and discard those two types of false views. This is done by means of cultivating verifying perceptual and inferential cognition.

criterion of conventional existence. When speaking of a "conventional truth," its truth is determined not by objective reality but by the mind. Objective reality cannot be the criterion for truth, for truth is of the mind.[27]

The [conventional] truths of the mind can be established only by the confusion[28] of grasping onto true existence. So when one speaks of "conventional truth," that is true for the mind that grasps onto true existence. However, the mind that establishes conventional reality must not be deluded.[29] It must be verifying.[30] It may be

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[27]Although this statement seems at first glance to suggest idealism, a subtler meaning is intended. According to the Centrist view, truth cannot be determined on the basis of some reality existing independently of the mind; for such a reality does not exist. However, this is not to say that there is no reality existing independently of the human mind. Precisely stated, the human mind can neither perceive nor conceive a reality independent of itself. Truth is determined on the basis of its knowability by a verifying cognition. A truth may not be known by a given individual or society, but this does not mean that it does not exist. If something is apprehended by any verifying cognition, it exists.

[28]moha, gti mug

[29]abhrānta, ma 'khrul ba. The Buddhist terminology in this section is very precise, and it is difficult to avoid confusion in the English translation. The mind that establishes conventional reality must not be deluded in terms of mistakenly apprehending its chief object. For example, a mind that believes in rabbit's horns is deluded with respect to its chief object, viz. rabbit's horns. A mind that establishes conventional reality is termed confusion only because it grasps onto true existence. It correctly identifies its chief object, but it mistakenly regards that object as truly existent.

[30]According to the Centrist view, a cognition is verifying if it unmistakenly apprehends it chief object.

deluded with regard to its apparent object, but it must not be mistaken[31] with regard to its chief object.[32]

When establishing our own [Prasangika] conventional reality, a cosmic primal substance and God do not exist even conventionally. Likewise, within the context of other Buddhist views, we do not grant even conventional existence to the "foundation consciousness"[33] or "self-cognition" that are posited by the Idealist system. We regard things like jugs as conventionally existent. Both [entities and non-entities] are mere conceptual designations and neither exists from its own side. In that sense they are alike; but there is a distinction as to whether or not they are conventionally able to render help or inflict harm and whether or not they are established by an verifying cognition. That cognition is indeed deluded insofar as it is deluded with respect to the appearance of true existence. But apart from that, there is a distinction between being mistaken or unmistaken with respect to its chief object; and that is what determines it verifiability. That is the difference between conventional existence and non-existence.

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[31] avisaṃvādaka, ma slu ba

[32] 'jug yul. For anyone but a Buddha, a fully awakened being, all conventional truths appear as if they were truly existent. Thus, when an ordinary person sees a mountain, it falsely appears to exist intrinsically from its own side. One may unmistakenly apprehend the mountain (the chief object), while being deluded with respect to its mode of appearance (the apparent object).

[33] alayavijñāna, kun gzhi rnam par shes pa

The criterion for conventional existence is the presence of a mind that is unmistaken with respect to its chief object. While ascertaining emptiness, one does not establish the existence of other entities. But upon rising from such meditative equipoise, if something appears clearly to the mind; if its conventional existence is not repudiated by any other conventional knowledge; if it is able to yield benefit or harm; and if it is established by verifying cognition--then it exists. If not, it does not exist even conventionally.[34]

108. The "conceptual mind" and the "conceived object" are mutually interdependent. All analysis is experienced in dependence upon, and in accordance with, common sense.

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[34]It has already been mentioned that there are generally two kinds of verifying cognition: perceptual and inferential. The former includes valid sensory cognitions as well as certain kinds of mental awareness in which objects are ascertained without the appearance of the ideas of those objects. Inferential verifying cognition apprehends its object in dependence upon conclusive reasoning; and such cognition is always mixed with the appearance of the idea of its object. Because of the twofold nature of verifying cognition, Tibetan Buddhist mental discipline entails training both in meditation and logic. The former is aimed primarily at cultivating subtle forms of perceptual, mental verifying cognition. With such training one can eventually ascertain for oneself the existence of such events as past and future lives. A central emphasis of this discipline is to learn to distinguish between verifying cognition and the fantasizing mind that conjures up all sorts of fictitious imagery.

Subjective conceptual cognition and conceived objects are mutually interdependent. Action depends on an agent of action, and the agent depends on action. For example, a tailor is identified on the basis of his [of her] activity of tailoring; and since there are tailors, the activity of tailoring occurs. This is not to say that the agent and the action are causally related, but they are mutually dependent.

In order to establish the ultimate mode of existence of some entity, one must first determine that the entity in question exists. On that basis one inquires into its mode of existence.

109. Investigating the analysis of a subject of inquiry leads to infinite regress, for that analysis would also be subject to investigation.

Here is the question of infinite regress:

Objection: You Centrists first analyze some subject like a jug; then you investigate the ultimate nature of the jug. In this way you enter into an infinite regress of analysis.

110. Upon analyzing a subject of inquiry, [one sees that] there is no [intrinsic] basis for that investigation. Since there is no basis, [that

analyzing mind] does not [intrinsically] arise, and that is called [natural] "Nirvana."

Upon analyzing a subject such as a jug, one ascertains the intrinsic emptiness of the jug. That awareness apprehends the simple negation[35] that is the mere absence of the true existence of that subject. It cognizes only that emptiness. It apprehends no other entity; it does not identify "this" as opposed to "that." As long as that mode of cognition lasts, the subject, or basis, whose lack of true existence was investigated, is not ascertained by the mind.

Upon establishing the lack of intrinsic existence of entities of form and so on, if one further proceeds to analyze that ultimate reality[36] of the lack of intrinsic existence, one ascertains the lack of true existence of ultimate reality. In this case the subject of analysis is emptiness, and one ascertains the ultimate reality of the ultimate reality of forms and so on. Thus, one speaks of the emptiness of emptiness.

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[35] med dgag

[36] dharmatā, chos nyid

PART THREE:

REFUTATION OF TRUE EXISTENCE

CHAPTER SIX:

REFUTATION OF OTHERS' CONCEPTIONS OF TRUE EXISTENCE

111. According to some, both [awareness and its object] are truly existent; but that is completely untenable. If the object [truly] exists by the power of the awareness of it, what then is the justification for the [true] existence of awareness?

Realists assert that both awareness and its object are truly existent; but that view is completely untenable. If the object is truly existent on account of the true existence of awareness, what grounds are there for maintaining the true existence of awareness?[1]

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[1]Here, once again, the Centrist view takes a stand essentially different from that of idealism.

112. Moreover, if awareness [truly] exists by the power of the object of awareness, what is the justification for the [true] existence of that object? Thus, as they exist by the power of each other, neither would be [truly] existent.

Moreover, if awareness is established on account of a truly existent object of awareness, what are the grounds for asserting the latter? It is appropriate to posit their mutually dependent existence. But if one is not satisfied with that and insists on an intrinsic basis for their existence, then inconsistencies are inevitable.

Thus, if verifying cognition and its object exist in mutual dependence--establishing each in relation to the other--neither would be truly existent. They would both exist as mere conventions in a relational sense; they would not exist by their own intrinsic natures.

113. Without a father there can be no son, for where would the son come from? But in the absence of a son there is no father. Similarly, both [awareness and its object] are not [truly] existent.

A father and child exist relative to one another. Without a child, a father cannot be posited. It is strange:

Until a child is [physically] conceived, a man is not a father, for he canot be labelled as such. Thus, "father" is posited in relation to a child, and before a child is conceived there is no father. Once a child is conceived, there is a father. And yet one says that a child is sired by its father. The man whose seed goes to help produce a child is not a father prior to conception, but in reference to the child that will be produced later on, one can speak of the father who sired the child. If one analytically seeks out the father on his own, his existence canot be posited. Thus, the two are established relative to one another.[2]

114. Since a sprout arises from a seed, the [true existence of] the seed is thereby revealed. Since awareness arises from an object of knowledge, why is its [true] existence not ascertained?

Realist: One can infer the true existence of a seed by

[2]The mutual dependence between father and child is obvious in terms of language. And because, conventionally speaking, there can be no father without a child or child without a father, this is true of the reality that is imputed by convention. The same is true of the mutual dependence between cause and effect: One cannot speak of a cause without an effect or vice versa. Thus the two are interdependent in terms of language and conventional reality.

the fact that it produces a sprout.[3] Likewise, why can one not realize the true existence of an object of knowledge, since awareness arises in dependence on it?[4]

115. The existence of a seed is understood because of a cognition that is different from the sprout. But whence comes an ascertainment of the [true] existence of awareness simply because an object of knowledge is apprehended?

Centrist: By ascertaining the causal relationship, one can know that a seed preceded a sprout. And one can know that an object of knowledge exists since it acts as a causal, objective condition for the arisal of the resultant

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[3]This is the Realists' major rationale for asserting the true existence of natural phenomena: They are causally interrelated, so they must exist independently of conceptual designation. The Centrist replies: It is precisely because such interrelationships occur that it is impossible for those phenomena to be self-defining, intrinsic entities.

[4]Here is another major Realist argument: The world about us must truly exist, otherwise we would not share, common experience of it, which arises in dependence upon that independent, objective world. Indeed, until one has deeply explored the role of consciousness in the universe, the above conclusion seems inescapable. Western science has hardly begun to make such an exploration, so it naturally assumes the true, independent nature of the cosmos. Buddhist contemplative science has long engaged in such empirical investigation into the nature and function of consciousness; and it accounts for shared, common experience in terms the role of shared actions in previous lives and their effects in this life.

awareness of it.[5] While apprehending an object of knowledge, by what verifying cognition is the awareness of that object ascertained?

[5]Note that the Centrist view acknowledges the role of objective conditions for the arisal of perceptions of the natural world. But it denies that those conditions exist independently of mental imputation.

CHAPTER SEVEN:

PROOFS OF THE ABSENCE OF TRUE EXISTENCE

The "Diamond-Splinters" Argument

116. People do indeed perceptually observe all [kinds of] causes. The individual parts of a lotus, including its stalk and so on, are produced by various causal conditions.

Now the author establishes the lack of intrinsic existence of causes. First he makes a point of denying the absence of causality. For example, the individual parts of a lotus are produced by a variety of individual causes.

117. What makes the various causes?--a previous variety of causes. What makes a cause able to produce an effect?--the power of previous causes.

What accounts for the variety of causes? They too occur in reliance upon causal conditions. The ability of distinct causes to produce various distinct results is due to the power of each one's preceding cause.[1]

118. If you assert that Ishvara is the cause of living beings, by all means let us know: Who [or what] is Ishvara? You may reply: "the elements." That may be, but then why even trouble yourself with a mere name?

As mentioned before, the qualities of our environment and of sentient beings arise from causes, specifically by the power of individuals' actions. The ability of good and bad causes to produce good and bad results is due to the individual preceding conditions for those causes.

Objection: That is not right. Is there not a God who

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[1] Buddhism very clearly asserts the importance of causality in the arisal of both physical and cognitive natural events. Recall that mind is considered to be as much a constituent of the universe as matter or space; and causal relationships pertain equally in cognitive and physical events as well as to the interactions between those two types of phenomena. Prevailing interpretations of quantum mechanics emphasize the lack of strict causality in the quantum world. This view, which first became popular in Western Europe during the era between the two World Wars, prefers the themes of chaos, randomness and uncertainty governing the basic constituents of the natural world. This historical context does lead one to ponder the extent to which this ontological view was influenced by the social and economic climate of the times. In any case, it is a complete fallacy to equate the Buddhist view of causality with either the mechanistic determinism of classical physics, or the probabilistic determinism of quantum physics.

is the cause of creation and destruction? Was the world not created by Ishvara[2]?

Response: If you assert that God is the elements of Nature, we agree with you. There is no fault in maintaining that living beings and the environment arise from the elements. But there is no point in giving those elements the further name of "God."

119. Furthermore, the earth element and so on are manifold, impermanent, inert and not divine; they are stepped upon and are impure. That is not God.

Moreover, Ishvara is thought to be a unity, with absolute power and immutable permanence. The earth element and so on are many, impermanent, lacking a conscious ability to move the elements, etc. and are not divine. They [e.g. earth and water] are stepped upon and are impure. Thus, they cannot be a sacred God.

120. Space is not the Mighty Lord, for it is inert; nor is the self, for it has already been refuted. If the being of the Creator is inconceivable, whatever is there to say of that which is beyond thought?

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[2]As implied by the context, "Ishvara" is regarded in Hinduism as the personal Creator of the universe.

Empty space cannot be regarded as God, the Creator, for it is inert, being incapable of giving help or harm. Space is divorced from any kind of action, and thus it is not God. A [permanent] self, or soul, is not God, for its existence has already been repudiated. It may be argued that God is inconceivable by ordinary people, but that is of no help.

121. What does Ishvara desire to create? The soul? Is not the nature of the soul, earth and so on, and the Lord immutable? Awareness is due to an object of awareness, without beginning.

What is it that Ishvara creates? The soul? Do you not maintain that the soul, the atoms that make up the four elements, and Ishvara are immutable? [If Ishvara is a Creator and the rest are creations,] this undermines your assertion of immutability.

According to our view[3], sentient beings and our environment are produced by our own actions. Tracing the source of actions leads one to the mind. Thus, the source is awareness. This is not to say that the world is of the nature of consciousness. Actions are brought forth by wholesome and unwholesome states of awareness, and on this basis the world of phenomena is established.

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[3] cf. verse 117.

Now awareness arises, taking on the image of its object, and it is the mere cognition of that object. Thus, conventionally speaking, awareness arises from its object. If one seeks that imputed object [awareness], it is not found. But without such analysis, one can posit consciousness simply in terms of appearances and conclude that it arises from its object.

Each specific state of awareness arises in dependence upon its own object, but fundamental consciousness is without beginning. From beginningless time it exists as simple awareness, or cognition, in an ongoing continuum.[4]

122. And joy and sorrow are due to action; so tell us:
What is created [by Ishvara]? If the cause is
without beginning, how could its effect have a
beginning?

[4]According to Buddhism, no new continuums of consciousness are ever created. The mental continuum of every sentient being traces back to beginningless time. A wide variety of life forms are taken on by each consciousness in diverse physical realms of existence. A sentient being may even dwell in a formless realms which are unaffected by the cycles of cosmic origination and destruction. Moreover, while one cosmos is undergoing total destruction, making it unfit for any type of corporeal life forms, others are being born, while yet others are abiding in a habitable state. Buddhist cosmology asserts the existence of countless worlds inhabited by countless sentient beings including humans, animals and a myriad of other life forms. Even our own planet is the home of many non-human, non-animal sentient beings. Although normally hidden from human senses, they can be apprehended upon refining one's consciousness by means of certain types of meditation.

Specifically, joy and sorrow occur as a result of actions that are committed with wholesome and unwholesome states of mind. According to our view, the production, transformation and destruction of all natural phenomena can be understood without resort to the hypothesis of a Creator God.[5] Moreover, if you believe that God is an immutable, eternal cause having no beginning, how could there be a beginning to the effects of that cause?[6]

123. Why would they not always be produced, for Ishvara
does not depend upon anything else? Since there
is nothing that is not created by Him, upon what
would He possibly depend?

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[5]In his paper entitled "Science and Religion" Albert Einstein declares: "The main source of the present-day conflicts between the spheres of religion and science lies in this concept of a personal God." [Out of My Later Years, A. Einstein (Philosophical Library, N.Y., 1950) p. 27]. Buddhism denies the existence of a Creator God, as it attributes the creation of the world to natural events rather than to a source beyond nature. It is essential to keep in mind, however, that by "natural events" Buddhism includes many phenomena, including consciousness, which Western science normally excludes from the natural world.

[6]The notion that the universe and all the sentient beings who dwell in it have no ultimate beginning is often hard to grasp by the Western mind. Although the distortions and obscurations of an individual stream of consciousness have no beginning, they are irrevocably dispelled upon full awakening. The conscious continuum of a Buddha then continues on to the endless future; and the limitless activities of a Buddha focus entirely on leading others to spiritual awakening. Western thinkers are often accustomed to thinking in terms of ultimate beginnings, and both in the spheres of religion and science they are admonished not to ask what happened prior to such beginnings. Buddhism denies any beginning to time, and it refutes the existence of a Creator existing outside of time on the grounds that there is no verifying cognition of either.

Since Ishvara is believed to be immutable, if He produces something, it should be produced always. So why are all the effects of Ishvara not created simultaneously at all times? If there is nothing else that is not produced by Ishvara, He could not be influenced by any other conditions that might arise. He would be responsible for everything that occurs.

124. On the other hand, if [Creation] were dependent [upon conditions], the complete collection [of those causal circumstances] would be the cause, and not Ishvara. If the complete conditions were assembled, [Ishvara] would be powerless not to create; and if they were absent, there would be no creation.

If creation and destruction are dependent upon a collection of causal conditions, the totality of those conditions would be the cause, and not a God who is independent of and uninfluenced by events. If the causal conditions were assembled, Ishvara would be powerless not to create the resultant phenomena; and if they were not assembled, those phenomena would not be produced.

125. If Ishvara acts without desiring to, it would follow that He is dominated by something else. Even if [He acts] with the desire [to act], He would be dominated by desire. In that case, what of [your concept of] divinity?

If, when causal conditions are assembled, Ishvara is forced to create against His will, He would not be Lord of all Creation. Rather, He would be dominated by something else. Even if His actions are preceded by willful intention, He would not be independent and His actions would not be effortlessly spontaneous. Rather, He would be dependent upon His desires. Now desires are impermanent. They arise prior to action and cease upon the completion of the desired action. Thus, the belief in an immutable God is repudiated.

126. Moreover, those who claim that permanent atoms [are the source of Creation] have already been refuted. The Samkhyas assert a primal substance as the permanent cause of the world.

Here is a reference to a Vaisheshika assertion, namely that permanent, atoms are the creators of the various

universal consituents are not [truly] found, for
each one of those has three parts as well.

If the primal cosmic substance is posited as a partless unity, it is contradictory to maintain that it has the three natures of sattva, rajas and tamas. Thus, a primal substance that exists as an equilibrium state of the three universal consituents does not exist. It is inconsistent to claim on the one hand that it is a truly existent unity with no parts, and then on the other that its nature is the equilibrium state of three constituents.

Likewise, the theory of the three universal consituents does not hold up. Each of them is not a truly existent unity, for each of them is a composite of all three constituents. Thus, one speaks of the "rajas element," the "tamas element," and the "sattva element" of the activity constituent and so on.[8]

129. And if the universal constituents do not [truly]
exist, the [true] existence of sound and so forth
is far-fetched. It is also impossible for there

[8] A contemporary explanation of them can be found in I.K. Tainmi's <u>The Science of Yoga</u> (The Theosophical Publishing House, Wheaton, Ill., 1981), pp. 171-179. For a more traditional account see Swāmi Hariharānanda Āraṇya's <u>Yoga Philosophy of Patañjali</u> (State Univ. of New York Press, Albany, N.Y., 1981), pp. 158-169.

to exist joy and so on in mindless things such as cloth.

The theory of a primal substance and truly existent universal constituents is faulty. Thus, the corresponding assertion that sound and so forth arise from them as manifestations of them is utterly implausible.

Moreover, it is impossible that mindless material objects such as cloth and more generally the five sense objects[9] are substantially identical with joy, suffering and equanimity.

130. You may claim that things are of the nature of the causes [of happiness, etc.], but have things not already been analyzed? [You believe that the universal constituents of] joy and so on are the causes, but such things as woven cloth are not due to them.

Things such as cloth are not of the nature of joy and so on. While you may say that the nature of the cause of cloth, etc. is truly existent, that subject has already been analyzed.[10] According to your system, the cause of such

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[9] tanmātra, de tsam. See Yoga Philosophy of Patañjali, pp. 169-170.

[10] cf. verses 78-87.

things as cloth is the primal substance, in which joy and so on are in equilibrium. But woven cloth and so forth do not arise from that.

131. Even though pleasure etc. may result from cloth etc., when those [causes] are absent, pleasure is no more. Thus, the permanence of pleasure etc. is never ascertained.

You may say that such things as woven cloth give rise to pleasure etc. We refute the arisal of woven cloth etc. in terms of repudiating its basis of manifestation.[11] If you claim that pleasure etc. are due to such things as woven cloth, we retort: Since woven cloth etc. no longer exists, the resultant pleasure etc. no longer exist either. Thus, the permanence of pleasure is never observed by means of verifying cognition.

132. If truly existent pleasure is observable, why is the experience of it not apprehended? If [you say that] it becomes subtle, how can it be gross and [then] subtle?

If observable pleasure is a permanent, real entity, when suffering is experienced, why is joy not experienced as

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[11] 'khrul gzhi

well? If joy is permanent, it should remain continually with no fluctuations. If it becomes subtle at times when strong suffering is present, then you must agree that it fluctuates from gross to subtle. But how can it be subtle sometimes and gross at other times, since you claim that it is immutably permanent?

133. It might be subtle after leaving its gross phase,
but then its grossness and subtlety would be
impermanent. Why then do you not accept all
things as impermanent in the same way?

If there is fluctuation, such that it is subtle after being gross, it must be acknowledged that it is impermanent. Why then do you not assert that all things such as pleasure and so on are impermanent?

134. Its grossness is not something separate from
pleasure, so the impermanence of pleasure is
evident.
You may believe that the unreal does not arise,
for it has no existence whatever. Still, [the
problem of] the arisal of a non-existent
manifestation remains for you, even against your
will.

If its grossness is not substantially different from joy, joy is obviously impermanent, for it fluctuates from grossness to subtlety.

Now the author refutes the Samkhya belief in "self-creation"[12]:

Samkyha: Any effect that is fundamentally non-existent at the time of its cause cannot arise. It must exist in order to arise. Thus, it cannot be utterly non-existent at the time of its cause; rather it exists potentially, but not manifestly. Then it arises into its manifest nature.[13] The manifest entity does not exist at the time of its cause, but its potentiality does exist.

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[12] ātmaja, bdag skyes. The Samkhya system, finding it difficult to accept that non-being can become being, asserts that the effect, even before it occurs, was being. However, the effect is only latently present in the cause, and its production makes manifest what is already latent. Thus, causation is only a manifestation of what is already potentially existing. On a cosmic scale, the world is produced from the primal substance, but this is simply a manifestation of what that substance already contains. This subject is discussed in S. Dasgupta's A History of Indian Philosophy (pp. 254-258) and P.T. Raju's The Philosophical Traditions of India (pp. 162-163). In his book Physics and Philosophy: The Revolution in Modern Science (Harper & Row, Pub., N.Y., 1962) Werner Heisenberg discusses his own belief in a "universal substance" (p. 61) and his theory that unmeasured atoms and particles exist as "potentia" (p. 186), which are not as real as the phenomena of daily life.

[13] Recall that Heisenberg regards unmeasured entities in the quantum world as existing as potentialities which, by the act of measurement, enter the actual realm of manifest reality. A parallel may be drawn between that view and the present Samkhya theory. The Centrist view refutes both insofar as they posit such potentialities as truly existent.

135. If the effect is present in the cause, to eat food would be to eat excrement; and with the price of cloth one may as well buy cotton-seeds and wear them.

Centrist: If the substance of the effect is present in the cause, as you believe, then when one eats food one would be eating excrement; for the latter would be present in the former.

136. You may claim that worldly people do not see this due to their confusion. But even for those who know reality that is the situation.

Samkhya: The effect is indeed present in the cause, but due to confusion, worldly people do not see this.

Centrist: Your teachers, such as the sage Kapila, who you believe directly know the nature of reality, would, according to you, realize that an effect is present at the time of its cause.

137. You maintain that knowledge of that exists in worldly people, too; so why do they not see it? If you counter that their cognition is not verifying, then their perception of manifest things is also unreal.

If the Samkhya belief that the effect is present in the cause is true, then worldly people should see this as well.[14] If worldly perception is not verifying, then such awareness of specific things in the world is not true.

138. If verifying cognition is not [ultimately] verifying, then indeed that which is known is deceptive. In reality the emptiness of phenomena is logically invalid.

Now the author responds to a criticism of the Centrist view:

Samkhya: Even according to your Centrist system, all states of awareness are deluded apart from a Superior's non-conceptual, meditative realization. So types of cognition that you call verifying are not ultimately verifying; even they are false. The verifying cognition that is the criterion for establishing the existence of entities exists only by the power of convention. It is not verifying due to any objective truth. Thus, objects that are known by that deluded "verifying" cognition must be false. In that case,

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[14]If this is a perception of realized beings, and worldly people will eventually become realized, then that resultant realization should already be present in them. Thus, they should see that effects are present in their causes, just as the sages of the Samkhya school do.

the verifying cognition that identifies emptiness is false; and thus emptiness, too, must be deceptive. Then there is no point in meditating on emptiness.

139. Not having experience any [true] thing as conceived, its non-existence is not perceived [as a true thing either]. Therefore, when an existent thing is false, indeed, its non-existence is clearly false [as well].

Centrist: If the appearance of true existence, which is falsely imputed by ignorance, is not found, one does not apprehend its unreality. Thus, by repudiating this false entity, the deceptive nature of its unreality is clear. Even emptiness exists by the force of convention. If one analyzes it in relation to the object that is empty of an intrinsic nature, that emptiness is found to be devoid of true existence.

In short, every possible entity, without exception, lacks an intrinsic nature. If there were anything at all that was not empty of intrinsic existence, emptiness might be truly existent. But since everything is empty, it is impossible that emptiness is not itself empty.

Further, Fundamental Wisdom states that if one realizes the meaning of emptiness, this invalidates conceptual grasping to true existence; and attachment and hostility can thereby be dispelled. This acts as a remedy for suffering and discontent. However, conceiving of emptiness as being truly existent is said to be an incurable view. This is a very striking statement.

Thus, even emptiness exists simply by the force of convention. It does not truly exist. It does not exist in an ultimate sense. What is meant then when emptiness is said to be ultimate truth? The word "ultimate" is used in different ways. As explained in Maitreya's treatise The Distinction between the Center and Extremes,[15] there are ultimate objects, ultimate cognitions and ultimate proofs. The word "ultimate" may be applied to objects and subjects. When the Two Truths are explained in Fundamental Wisdom, the word "ultimate" refers to an object--emptiness. That is common in teachings of the "Sutra tradition." In the "Tantra tradition" there are many instances when the same word is used in reference to the subjective mind. The "clear light"[16] state of awareness is frequently given the appellation "ultimate." Thus, one must be careful to recognize the context in which the word is used. Does it occur in explanations of the tantric Stage of Completion, or in the Stage of Development[17], in the context of the lower

[15] Madhyāntavibhaṃgakarikā, dBus mtha' rnam 'byed

[16] cf. Clear Light of Bliss, pp. 203-213.

[17] For an explanation of these two stages see Daniel Cozort's Highest Yoga Tantra (Snow Lion Pub., Inc., Ithaca, N.Y., 1986) pp. 39-114.

classes of tantra, or in sutra contexts that bear no reference to tantra? If one fails to recognize such distinctions, one is liable to become confused.

Thus, there is much to be understood from the term as it is used in <u>The Distinction between the Center and Extremes</u>. Moreover, in the Svatantrika system there are references to a "simulated ultimate"[18] and an "ultimate." Even though emptiness is one entity, when it is experienced together with dualistic appearance, it is called a "simulated ultimate." When it is experienced without any dualistic appearance whatever, emptiness is called "ultimate." Although emptiness is a single entity, this distinction is made in terms of the way it appears to the mind. The word "ultimate" is also applied to the mind.

A further twofold distinction in the usage of this term is made: (1) All possible entities are deceptive and are not truly or ultimately existent. The true existence that is refuted in that statement is called "ultimate." Thus, emptiness, too, is deceptive and not ultimately existent. It exists by the force of convention, not by its own intrinsic reality. (2) Now emptiness is also called "ultimate truth." To the ultimate mind[19] that seeks the fundamental mode of existence of, say, a pot, its mode of

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[18]mthun pa'i don dam

[19]This mind is called "ultimate" because it is involved in ultimate analysis of an entity, seeking its essential mode of existence.

existence appears. That mind does not find a pot, but the mode of existence of a pot. Since that mode of existence [i.e. the emptiness of an intrinsic nature of the pot] exists for that mind--since it is true for that mind--it is called "ultimate truth."

Thus, there is nothing whatever that is ultimate in the first sense, but in the second case the word "ultimate" is applied to something that does exist: a state of awareness that explores the fundamental mode of existence of entities. There are entities that are seen to exist by that mind, but they do not truly exist. If they were truly existent, they would exist by their own nature; and they should be apprehended by a mind that tries to determine whether or not they exist. If a pot were truly existent, it should be found by an ultimate mind that seeks the fundamental mode of existence of a pot.

The Buddha said that Nirvana is also emptiness. If there were something beyond Nirvana, it would be empty as well, in the sense that it would have no intrinsic nature. The finest entity--Nirvana--is emptiness. It was not newly created by the Buddha, nor by the minds of sentient beings. It has no intrinsic nature, but exists in a relative sense.

When we speak of emptiness, it may seem to be relatively impotent, for the entity that is empty [e.g. a pot] is more potent. We experience joy and sorrow due to the good and bad qualities of such entities; but there is no distinction of "good" and "bad" in terms of emptiness. It is strange: The mere absence of an intrinsic nature of an entity is emptiness, so emptiness seems sort of impotent. It depends upon that entity, so it does not exist on its own. It does not exist "apart from elaborations"[20]. There are many kinds of elaborations: dualistic elaborations, elaborations of subjects, conventional elaborations and so on. Since emptiness does not exist apart from the elaboration of the subject that is empty, emptiness does not exist on its own. The simple negation that is emptiness exists by the negation of true existence, so of course it is deceptive [in the sense of not being absolute].[21]

140. Thus, upon the death of a son in a dream, the thought "he does not exist" obstructs the arisal of the thought of his existence; and they are [both] deceptive.

Objection: What benefit is there in a deceptive, verifying cognition dispelling deceptive suffering?

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[20] niṣprapañca, spros pa dang bral ba

[21] Buddhist philosophy speaks of two types of negations: simple (med dgag) and complex (ma yin dgag). The former is the mere absence of something. Non-composite space, for example, is defined as the mere absence of obstruction, and it is, thus, a simple negation. A complex negation consists of the absence of something, together with the affirmation of something else. Thus, a treeless plain is a complex negation: Trees are negated, while the plain is affirmed.

Response: As it states in Fundamental Wisdom, everything is comprised of elaborations of elaborations, like deceptive illusions; but they are able to give benefit and inflict harm.

141. Therefore, such analysis reveals that there is nothing that is not due to a cause; and nothing is contained in either its single or combined causal conditions.

There is nothing that is produced without a cause, and nothing exists independently in either its individual or combined causal conditions.

142. An entity does not come from something else, it does not remain, nor does it depart. What is the difference between an illusion and that which is really fabricated by deluded people?

An effect is not present in any one of its causes nor in all of them together; it does not intrinsically remain upon having been produced; and upon its cessation, it does not go anywhere else.

The confusion of grasping to true existence falsely imputes true existence upon entities; but whether that imputation is upon the causes, nature or effects of an entity, in fact they all exist only by the power of convention. However, things do not appear to exist merely by convention but rather from their own side. Thus, objects do not exist in the way they appear, and in that sense they are like illusions.

The Interdependence Argument

143. You should deeply investigate whatever is created
by an illusion and whatever is created by causes:
Whence does it come and where does it go?

The point of this argument is that nothing is intrinsically created, abides or ceases. All phenomena are like illusions; they exist in a dependent fashion; and there is nothing that is independent.

144. One thing is seen by its juxtaposition with
something else, but not if that other thing is
missing. If something is artificially created,
like a reflection, how can it be reality?

An effect is observed if it is in proximity to its causes, but if those causes do not exist, neither does the effect. Thus, it does not exist independently; its own existence is dependent upon something else. Since an effect depends upon its causal conditions, it does not exist on its own. Moreover, it exists in dependence upon its own components. There is nothing that exists on its own, independently of its parts or attributes; and upon analyzing the individual parts, no whole is to be found.

The basis of an designation and the object designated upon that basis are never identical, and the object is never found among the components of its basis of designation. Since the object does not exist from its own side, it exists simply by the power of conceptualization, or convention.

There is nothing that exists independently, by its own intrinsic identity, so everything is imputed, artificially created and reflection-like. How then can anything exist in reality? This is the "interdependence argument": Since things exist in reliance upon causal conditions, in dependence upon other things, how can they be truly existent, for they are like reflections?

The Argument Concerning the Arisal and Cessation of Entities and Non-entities

145. If something truly exists, what does it need with
a cause? Moreover, if something is non-existent,
what does it need with a cause?

In general, existent things are produced, and non-existent things are not. However, in stating that entities are produced, if one means that they exist not simply by the power of convention, but by their own power, they would exist independently, without reliance upon other conditions. If something existed in that way, it would have no need for a cause, for it would already exist by its own power.

Moreover, if the phenomenon produced by its own power is non-existent--not non-existent due to an absence of contributing conditions--what good would causes do for it?

146. If something does not exist, there can be no
change in it, even by a million causes. How could
its state exist? What else could enter into a
state of existence?

Even a million causes are not able to make something [intrinsically] non-existent become [intrinsically] existent. If the state of non-existence is transformed into a state of existence, it must do so either by shedding or not shedding its non-existence. In the latter case, since existence and non-existence are mutually exclusive, how could its state be existent? This would be impossible. In the former case, apart from an existent and a non-existent, what else could become existent? There is no other possibility.

147. If something does not exist when it is non-existent, when does it become existent? And, by means of a not [yet] produced existence, a non-existent [state] will not be escaped.

When something is non-existent, it does not exist; so when does it become existent? The author thus refutes the existence of something that has not shed its non-existence. Moreover, if something is not produced, it does not depart from non-existence.

148. If something does not escape non-existence, it is impossible for its existence to emerge. And a [truly] existent entity cannot become non-existent, for it would follow [absurdly] that it is of a dual nature.

Since the two states of existence and non-existence are mutually exclusive, if something does not depart from non-existence, it cannot become an existent, nor can a [truly] existent entity become non-existent. Why? Because it would follow that one entity would have two mutually exclusive natures, and that is impossible.

149. In that way, never is there any [true] cessation or [true] existence; and therefore this entire universe is unproduced and unceased.

Thus, there is no intrinsic cessation due to the vanishing of causal conditions, nor is there any intrinsic reality that exists prior to cessation. Therefore, the entire universe, which arises and passes simply by the power of convention, is devoid of intrinsic production, duration and cessation.

150. States of living are likes dreams, on analysis coreless like a plantain tree. In reality, there is no distinction between those who are and are not emancipated.

Like a dream, if one analyzes states of living, they are seen to be devoid of an intrinsic essence, like a plantain tree.[22] Likewise, liberation and cyclic existence are devoid of an intrinsic nature, and in terms of ultimate reality there is no distinction between them.

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[22]From the outside, a plantain tree seems firm and solid, but if one penetrates it, one discovers that it has no core. Its appearance belies its reality.

CHAPTER EIGHT:

ENCOURAGEMENT TO STRIVE TO REALIZE EMPTINESS

151. Thus, among empty phenomena, what could there be to gain or lose? Who will be honored or despised by whom?

In summary, an individual--e.g. oneself--who abides in the cycle of existence, the dangers and suffering of this cycle, including mental distortions, and the attainment of Nirvana--in short, all entities--are empty of an intrinsic nature. Thus, what is to be attained, and what is to be lost? When one analyzes praise and blame, they are found to be not truly existent.

152. Whence come joy and sorrow, and what is pleasant and unpleasant? When it is analytically sought in reality, what craving is there, and what does it crave?

In terms of friends and enemies, why should one be displeased with those who are unfriendly and why be pleased with those who are friendly? If one seeks in terms of ultimate reality, who is it that craves, what is craved and what is the act of craving? None of the three members of that triad intrinsically exist.[1]

153. Upon investigation, what is this world of living beings, and who really will die here? Who will there be, and who was there? Who is a relative, and who is a friend ofwhom?

154. Let those who are like me apprehend everything as being like space. Due to the causes of strife, those desiring their own happiness are provoked to anger, and due to the causes of merriment they rejoice.

All phenomena are like space, and if they are investigated, one finds that they are not self-sufficient but lack an intrinsic identity. Initial understanding of emptiness will not immediately attenuate one's attachment and hostility; but by frequently familiarizing oneself with that understanding, one gradually approaches an actual

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[1]The triad of agent, action and object of the action is a frequent subject of analysis in the Centrist system. If we relate this to scientific research, we can speak of the person who makes a measurement, the system of measurement and the measured object. All three are mutually interdependent, and none bears an intrinsic identity. If the person in this triad reifies his or her own individual existence, there will be a tendency to reify the act of measurement and the measured object as well. From the Centrist perspective, this guarantees that such research will be conducted under a cloud of ontological confusion.

realization of emptiness. In that process, dualistic appearance gradually fades away, culminating in a direct, non-conceptual realization of ultimate reality. That acts as a direct remedy for speculative mental distortions,[2] but many other distortions are eliminated only upon the Path of Meditation.

So it is difficult. Simply knowing the meaning of emptiness does not suddenly free one from mental distortions. Rather, by repeatedly ascertaining emptiness, distortions can gradually be dispelled.

155. [Driven by disturbing] troubles and disappointments, they cut and stab one another and thus eke out an existence in great hardship by means of evil deeds.

Next the author writes of the disadvantages of not realizing emptiness. People who do not realize emptiness are enraged by sources of conflict and delighted by sources of joy. When their desires are not met, they experience

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[2]Speculative mental distortions are those that one acquires by adopting false views and so on. They have to be learned. Inborn mental distortions are those that one is born with. Thus, a newborn infant enters the world with mental obscurations carried over from previous lives; and these may then be compounded with speculative distortions that are adopted during its lifetime. Buddhist practice is aimed not at reverting to an infant-like state of consciousness, but at striving toward an unprecedented state of awakening. Inborn mental distortions are finally dispelled only as one develops on the Path of Meditation.

misery; and for that sake they exert themselves, argue with one another, and cut and stab each other. By such various evil deeds they make a living in great hardship.

156. Having repeatedly entered fortunate states of existence and experienced delightful joys, the dead fall to miserable destinations in which there is protracted, violent anguish.

Even in this life, due to attachment and hostility, there is little joy but great hardship. In the hereafter most people wander in miserable states of existence. Even when in a fortunate state of existence, they do not investigate the root of the cycle of existence or meditate on emptiness; and as a result they descend again to miserable destinations. There they experience protracted, violent suffering.

157. There are many abysses in the world, and no such [understanding of] reality is to be found there. [Ignorance and understanding of reality] are mutually incompatible, and in cyclic existence there is no such [understanding of] reality.

There are many abodes of suffering, and in the many abysses of the cycle of existence there is ignorance of the nature of reality. Thus, one is bound to this cycle by the fetters of craving.

Grasping onto true existence is incompatible with experiencing the nature of reality, and thus in this cycle of existence people do not ascertain reality.

158. And there are boundless oceans of incomparable, violent suffering. Thus, there is feebleness and short lifespan as well.

In this cycle of existence manifold types of suffering and discontent are to be experienced, and one has little ability to engage in wholesome activity.

159. There, too, [they seek] long life and health by means of their occupations, with hunger, exhaustion, weariness, sleep and calamities, and with meaningless association with childish people.

160. Thus, life passes by swiftly and in vain, with very little opportunity for discrimination [between good and bad]. Where is there a way to prevent habitual distraction?

161. There, too, Mara tries to cause beings to fall to

deeply wretched states; and due to a multitude of false paths, doubt is difficult to overcome.

People let their time pass in distractions, and the wisdom of investigating the nature of phenomena is exceedingly rare. Even if there is some modest inclination toward spirituality, due to habituation with distraction, it does not tend to be sustained, nor go very deep. It is difficult to remedy that habituation.

Furthermore, much harm is wrought by Mara[3] and other such entities, which obstruct people's spiritual practice. In this world there are a great many false paths that lead to suffering. For instance, there are extreme views such as nihilism; and there is agnosticism, which is difficult to transcend.

162. It is difficult to obtain leisure[4] again, and the presence of a Buddha is extremely hard to find. It is difficult to restrain the flood of mental

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[3]The "devil" for Buddhists. The term "Mara" is used sometimes in the singular and sometimes in the plural.

[4]In Buddhist literature "obtaining leisure" refers to meeting with outer and inner conditions that are crucial for fully effective spiritual practice. Eighteen factors of "leisure" and "endowment" are frequently discussed in this regard. See Sonam Gyatso, the Third Dalai Lama's Essence of Refined Gold, trans. and ed. Glenn H.Mullin (Gabriel/Snow Lion, Ithaca, N.Y., 1982) pp. 58-62.

distortions. Alas, suffering continues uninterruptedly!

163. Alas for those in intense grief, for those adrift in a flood of suffering, for those in terrible situations who, nonetheless, fail to recognize their own miserable state!

While abiding in limitless suffering, people do not recognize their own state of existence, their own discontent. Rather, they mistake suffering for happiness. They are worthy of our sympathy.

164. Some people repeatedly perform ritual ablutions followed by entering fire. Although they dwell in a state of misery, they think they are in a fine condition.

165. For those who pretend that there is no aging or death terrible calamities are encountered and they are slain by them.

Those who act carefreely, as if they were Liberated Beings who had overcome aging and death, are first slain by impermanence,then fall to miserable destinations.

166. With the rain of my joy that springs forth from the clouds of virtue, when might I be able to soothe those who are tormented by the fires of misery?

167. By having gathered the store of merit and by not seizing upon conventional truths, when might I manifestly demonstrate emptiness to those who have fastened on false views?

Might I realize the basis, path and fruition of spiritual practice without grasping onto true existence, but recognizing their mere conventional existence. Might I accumulate virtue with a motivation of compassion. With a unification of my practice of wisdom [viz. realization of emptiness] and my practice of virtue, motivated by compassion for sentient beings, might I become fully awakened. Might I reveal emptiness to those limitless sentient beings who are afflicted by grasping unquestioningly onto true existence. Thus, a Bodhisattva prays that any ability resulting from meditation on emptiness may be used only to bring about the welfare of others.

APPENDIX I:

ZERO-POINT ENERGY

Simple harmonic oscillation and the birth of quantum mechanics

To understand the nature of zero-point energy, let us first turn to the concept of the simple harmonic oscillation of a electromagnetic field in a cavity. Focussing on just one dimension of the cavity, we set its length equal to L, then pose the question: What wavelengths will fit? Since the walls of the cavity must coincide with nodes of the electromagnetic waves within, the longest possible wavelength would be 2 L. Thus, with the above boundary conditions:

$$\begin{aligned} \lambda_1 &= 2L \\ \lambda_2 &= L \\ &\vdots \\ \lambda_n &= \lambda_1 / n \end{aligned} \qquad (1)$$

Each of those wavelengths is associated with a frequency by the relation:

$$\nu_n = c/\lambda_n \qquad (2)$$

The set of frequencies $\{\nu_n\}$ is comprised of all the allowed frequencies of the electromagnetic field that oscillate in the cavity. They are called the modes of oscillation of that system. If one were to introduce radiation of all frequencies into the cavity, there would occur destructive interference except at those frequencies. While allowed frequencies are well defined due to the boundary conditions, the amplitude is determined by the initial conditions. The foregoing quantization of the frequency is a purely classical result.

Max Planck was concerned with the closely related problem of the thermal radiation in a cavity. Experimental measurements were made of the power radiated out of a small hole in a cavity, and it was found that the energy density spectrum approaches zero for high frequencies. Classical thermodynamics, however, predicted that the energy density should approach infinity as the frequencies approached infinity. This discrepancy was known as the ultraviolet catastrophe.

In order for the energy density to approach zero as the frequency approaches infinity, the average energy per mode must depend on the frequency and approach zero as approaches infinity. Planck solved this problem by postulating that not only the frequencies in the cavity, but the energy that is absorbed and emitted by the atoms of the cavity walls is quantized, according to the equation

$$E_n = nh\nu, \tag{3}$$

where h is a constant, now known as Planck's constant. The actual equation he derived for the energy density distribution as a function of wavelength was

$$u(\lambda) = \frac{8\pi hc\lambda^{-5}}{e^{hc/\lambda kT} - 1} \qquad (4)$$

where k is Boltzmann's constant, c the speed of light, and T the absolute temperature.

On that basis a quantization of the radiation field is made by associating a harmonic oscillator with each allowed energy state. This quantization may best be understood first in terms of a mechanical analogy.

Mechanical analogy

For our analogy we take a crystal solid formed of N identical atoms in a regular array, and we shall focus on a linear chain of atoms that are constrained to longitudinal vibrations.[1] The system thus has N degrees of freedom, corresponding to each atom's displacement from equilibrium. According to classical mechanics, the total energy of the system is

$$E = \sum_{i=1}^{N} \tfrac{1}{2} m\dot{q}_i^2 + V(q_1 \ldots q_n), \qquad (5)$$

[1]The source of this explanation of the analogy is I.J.R. Aitchison's article "Nothing's plenty: The vacuum in modern quantum field theory" in Contemporary Physics, 1985, Vol. 26, No. 4, pp. 333-391.

where m is the mass of each atom, and $q_i(t)$ is the displacement of the "ith" atom. We need to be able to express equation (5) in a form that entails a sum of N independent functions of displacement, which is possible with a linear transformation of variables,

$$Q_i = \sum_{j=1}^{N} a_{ij} q_j, \qquad i = 1,2 \ldots N. \tag{6}$$

With this device we can rewrite equation (5) in normal coordinates as

$$E = \sum \tfrac{1}{2} m \dot{Q}_i^2 + V(Q_1 \ldots Q_N). \tag{7}$$

If the values of Q_i are small enough we can regard each atom as a harmonic oscillator, in which case the potential energy V is a quadratic function of Q_i. With this stipulation equation (7) becomes[2]

$$E = \sum_{i=1}^{N} \left[\tfrac{1}{2} m \dot{Q}_i^2 + \tfrac{1}{2} m \omega_i^2 Q_i^2 \right]. \tag{8}$$

Each separate term in equation (8) is associated with a simple harmonic oscillator with its own frequency ω_i, called a <u>normal frequency</u>. If all the atoms in the crystal lattice move in a correlated fashion characterized by a single frequency, the total energy of the system is characterized by just one of the mode energies. That frequency is associated with a <u>normal mode</u> of oscillation. There are a

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[2]For a fuller explanation of normal modes of oscillation, normal coordinates and a full derivation of this equation see <u>Mechanics</u> by John C. Slater and Nathaniel H. Frank (McGraw-Hill Book Co., Inc., 1947) pp. 122-135.

definite number of normal modes, each with its own frequency. Since equation (8) can be written as the sum of N mode energies, the crystal lattice behaves as if it consisted of N separate harmonic oscillators. It should be clear that those oscillators are not identical with the individual oscillating atoms; for each atom participates in every normal mode of oscillation.

The simple harmonic oscillator in quantum mechanics

As mentioned above, quantum mechanics, following the lead of Max Planck, quantizes the absorbtion and emission of energy. In classical mechanics the energy of a simple harmonic oscillator can be reduced to zero simply by bringing it to equilibrium with zero velocity. Thus, both the position and the momentum of the oscillator are precisely defined. In quantum mechanics, however, the more precisely the position is defined, the greater the uncertainty in the momentum. This follows from Heisenberg's uncertainty principle

$$\Delta x \, \Delta p \geq \tfrac{1}{2}\hbar \, , \qquad (9)$$

where Δx and Δp are the standard deviations in position and momentum, and $\hbar = h/2\pi$. Now the average value of the momentum $\langle p \rangle$ could equal zero if there were equal deviation about the origin, but since $E = p^2/2m$, the negative signs disappear due to the factor p^2. Thus, the average value of $\langle \Delta p^2 \rangle$ cannot equal zero, and it immediately follows that the lowest energy state of a simple harmonic oscillator must be greater than zero. There are numerous ways in quantum mechanics[3] to show that the energy values of the allowed states of a simple harmonic oscillator are given by

$$E = (n + \tfrac{1}{2})\hbar\omega, \qquad n = 0, 1, 2 \ldots \tag{10}$$

The lowest possible energy, known as the zero-point energy, is

$$E_0 = \tfrac{1}{2}\hbar\omega . \tag{11}$$

In our mechanical analogy we spoke of mode energies of the solid, each one associated with a simple harmonic oscillator. Applying equation (1) to this system, we find that for each mode frequency ω_i, the energy values of the allowed states are

$$\varepsilon_i = (n + \tfrac{1}{2})\hbar\omega_i, \qquad n = 0, 1, 2 \ldots \tag{12}$$

The total energy of all the modes equals

$$E = \sum_{i=1}^{N} (n_i + \tfrac{1}{2})\hbar\omega_i . \tag{13}$$

The energy of each mode oscillator is quantized in units of $\hbar\omega_i$; and in a state with a vibrational energy of $(n_i+\tfrac{1}{2})\hbar\omega_i$, there are n_i quanta of energy. An elementary quantum of vibrational excitation of the crystal lattice is called a phonon.

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[3] This can be done, for example, by solving the Schrödinger equation for a simple harmonic oscillator: $(p^2/2m + \tfrac{1}{2}kx^2)\,\Psi(x) = E\,\Psi(x)$.

Concerning ourselves now with a linear array of atoms that are constrained to longitudinal vibrations, we take the limiting case of the number of harmonically interacting degrees of freedom $N \to \infty$, and the interatomic spacing $a \to 0$. We now have a continuous string of atoms of length $N \cdot a = L$. Longitudinal vibrations of the string are described by a "field" q(x,t), where at each point x on the string q(x,t) measures the displacement from equilibrium at time t. The field q(x,t) therefore obeys the standard wave equation

$$\frac{1}{c_s^2}\frac{\partial^2 q}{\partial t^2} = \frac{\partial^2 q}{\partial x^2}, \tag{14}$$

where c_s equals the velocity of wave propagation on the string. If the string is stretched between the points x=0 and x=L, the field equation can be written as

$$q_n(x,t) = A_n(t)\sin(n\pi x/L). \tag{15}$$

Inserting equation (15) into (14) yields[4]

$$\frac{d^2 A_K}{dt^2} = -\omega_n^2 A_n, \quad \text{where} \quad \omega_n^2 = \frac{n^2\pi^2 c_s^2}{L^2}. \tag{16}$$

Now on the basis of equation (8), the total energy of the string is

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[4]For an elaboration on equations (15) and (16) see Mechanics, pp. 146-151.

$$E = \frac{1}{2} L \sum_{n=1}^{\infty} (\rho \dot{A}_n^2 + \rho \omega_n^2 A_n^2), \tag{17}$$

where ρ is the density of the string. If we quantize the energy states of the string, we find the total energy to be

$$E = \sum_{i=1}^{\infty} (n_i + \frac{1}{2}) \hbar \omega_i . \tag{18}$$

With the above mechanical analogy in mind, we return to the system of an electromagnetic field in a cavity. Now c_s is replaced by c, the speed of light. As in the case of the string, the total energy of the system can be written as a sum of mode energies, and each mode has the form of an oscillator. Each oscillator is quantized, and the elementary quanta of excitation of the electromagnetic field are called photons.

An obvious distinction between phonons and photons is that the former occur in a medium of vibrating atoms, whereas no medium is posited for the latter. A similarity is that the ground state of the string field contains no phonons, just as the ground state of an electromagnetic field contains no photons. The latter state is known as an electromagnetic vacuum. The classical view assumes that such a vacuum contains nothing. In quantum theory, however, different conclusions are drawn due to the uncertainty principle.

Zero-point energy of the vacuum

To explore the energy of the electromagnetic vacuum, let us return briefly to our mechanical analogy. Recall that according to equation (16), the mode frequencies are given by

$$\omega_n = n\pi c_s / L. \tag{19}$$

For a cubical cavity of length L, there could be different mode frequencies ω_l, ω_m and ω_n in each dimension. Thus, the electromagnetic mode frequencies as a function of L give the relationship

$$\omega_{lmn}(L) = c\left[(l\pi/L)^2 + (m\pi/L)^2 + (n\pi/L)^2\right], \tag{20}$$

where l, m, and n are integers.

Since we have no justification for positing an upper limit to the frequencies in the cavity, the total mode energy is

$$E = \sum_{i=1}^{\infty} (n_i + \tfrac{1}{2})\hbar\omega_i$$
$$= \sum_{l=1}^{\infty} (n_l + \tfrac{1}{2})\hbar\omega_l + \sum_{m=1}^{\infty} (n_m + \tfrac{1}{2})\hbar\omega_m + \sum_{n=1}^{\infty} (n_n + \tfrac{1}{2})\hbar\omega_n. \tag{21}$$

The occupation number n_i refers to the number of photons in the mode with frequency ω_i. When $n_i=0$ for all i, we are faced with an electromagnetic vacuum. The energy of that vacuum is the zero-point energy of the electromagnetic field, and it is given by[5]

$$E_o = \sum_{i=1}^{\infty} \tfrac{1}{2}\hbar\omega_i \ . \qquad (22)$$

Now equation (17) indicates that the total energy of the one-dimensional field is proportional to L, so it follows that the total energy of the three-dimensional field must be proportional to L^3. This is equally true for the three-dimensional electromagnetic field. Moreover, the energy density of the vacuum is

$$\varepsilon_o = E_o / L^3 \ . \qquad (23)$$

According to equation (20), for large L, the mode frequencies will be so close together that equation (22) may be replaced by an integral

$$\varepsilon_o = \tfrac{1}{2}\hbar \int_0^{\infty} \omega \, N(\omega) \, d\omega , \qquad (24)$$

where $N(\omega)$ equals the density of modes per volume L^3.

What is the density of modes for each frequency? Equation (20) can be written as

$$\omega_{lmn}^2 = \frac{c^2\pi^2}{L^2} \left(l^2 + m^2 + n^2 \right), \qquad (25)$$

which is the equation of a sphere. Let P equal the number of modes within that sphere of radius ω_{lmn}. It follows that P is proportional to the volume of that sphere, namely $4/3(\pi \omega_{lmn}^3)$, since l, m, n>0. Following the stipulation for

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[5]This equation ignores degenerate states of frequency, which are accounted for in equation (24) by the factor $N(\omega)$.

equation (24), we find that the density of modes per unit frequency equals $dP/d\omega$ which is proportional to ω^2. At this point we can leave rigorous calculation, for it is evident that the energy density goes to infinity. Since $N(\omega) \propto \omega^2$, it follows that

$$\mathcal{E}_0 = \lim_{m \to \infty} \int_0^m \omega^3 d\omega \propto \lim_{m \to \infty} m^4 = \infty \, . \tag{26}$$

This indicates that $\mathcal{E}_0$ not only diverges, but does so increasingly rapidly for high frequencies, with no damping effect.

Simply stated, the energy density distribution of the electromagnetic vacuum approaches infinity as the frequency approaches infinity. Thus, the ultraviolet hydra whose suppression heralded the quantum revolution rears its head once again. Previously it manifested in the thermodynamic spectrum of the vacuum, whereas now this divergence appears in the zero-point spectrum. In the former case it was deemed a catastrophe because it was incompatible with experimental data. Such an experimental discrepancy with the theory has not occurred in the latter case, so the infinite energy density of the vacuum may be regarded simply as an ultraviolet embarrassment.

Is this divergence a quality of physical reality, or is it merely a mathematical anomaly? At present physicists simply do not know, but certain evidence such as the Casimir effect suggests that it warrants serious attention.

APPENDIX II:

THE CASIMIR EFFECT

On May 29, 1948, H. B. G. Casimir presented a seminal paper entitled "On the attraction between two perfectly conducting plates."[1] His major thesis can be summarized as follows: Although the divergence of electromagnetic energy even in the vacuum cannot be avoided for a single cavity, a finite <u>difference</u> between the energies of two cavities can be calculated; and this manifests as an attractive force exerted between the walls of the cavity. Using this method he demonstrates that the electromagnetic field in the vacuum does not vanish; it persists and evidence of its fluctuations can be found.

Casimir's theoretical treatment concerns "perfectly conducting plates," and this is an important assumption in his argument. By definition, there are no electromagnetic fields in such plates, which therefore restricts the cavity fields to having nodes at the boundaries. Moreover, the penetration depth of electromagnetic radiation is zero for such plates, allowing for precise calculations of the cavity dimensions.

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[1] H.B.G. Casimir, Proc. kon. Ned. Akad. Wetenschap <u>51</u> (1948) 793.

Experimental scientists never observe perfect conductors; they are an idealization. This approach of dealing in idealizations, abstracted from experience, was initiated chiefly by Galileo and has been extremely prevalent in physics ever since. The fact that it is based on a set of fictions that correspond to nothing in our experience suggests to some philosophers of science that physical theories do not describe objective physical processes.[2]

This criticism has been of little concern to practicing physicists, however, for the approach has been so enormously useful that its validity is hardly called into question. Indeed, if theoretical physics were forced to discard idealizations and concern itself with the immensely complex factors that are inherent in experimental situations, it would grind to an immediate halt.

That this approach is useful for predicting experimental results (to a certain approximation) and for creating new technologies is undeniable. But do such idealizations (e.g. undamped force, monochromatic light, absolute zero of temperature, and the perfect vacuum) exist in physical reality? A neo-Platonist might argue that they do indeed exist in an objective world of which only approximations are accessible via our instruments of

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[2]See The Structure of Science, by Ernest Nagel (Hacket Pub. Co., Indianapolis, 1979) p. 142.

measurement. The fact that more precise experimental procedures yield results that more closely correspond to ideal predictions seems, to some people, to substantiate this view.

Let us now examine in detail Casimir's theoretical argument. He begins by considering a cubic cavity of volume L^3 bounded by perfectly conducting walls. Let a perfectly conducting plate with sides of length L be placed in this cavity parallel to the xy-face. Now let us consider the situation in which this plate is an a small distance a from the xy-face and the situation in which it is at a very large distance, say $\frac{1}{2}L$. In both cases, the total energies $\frac{1}{2}\Sigma\hbar\omega$, summed over all resonance frequencies of the cavities are divergent.[3] Casimir therefore deems those expressions "devoid of physical meaning," presumably on the grounds that infinite energies cannot be measured.

Casimir goes on to suggest that the <u>difference</u> between these sums in the two situations has a well-defined value which can be interpreted as the interaction between the plate and the xy-face. The difference in the divergent energies of the cavity in those two situations determines the interaction between the two plates. For example, between two <u>charged</u> plates there exists a certain potential energy. To move them closer, that potential energy has to

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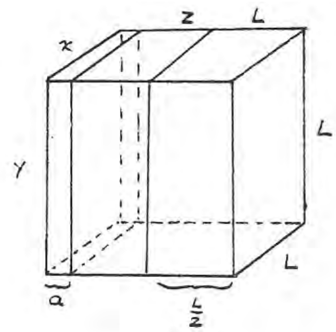
[3]See Appendix I, equation (22).

be changed. Now in our case, with uncharged plates, there is still a change, or difference, in potential energy between the two plates. That difference is the interaction potential between them. Since the negative of the gradient of that potential energy equals a force, there must be a force acting on the plates, which is derived from the energy of the vacuum.

Figure I.



Let us now consider the cavity depicted in Figure I. The possible vibrations of a cavity defined by

$$0 \le x \le L \qquad 0 \le y \le L \qquad 0 \le z \le a$$

have wave numbers

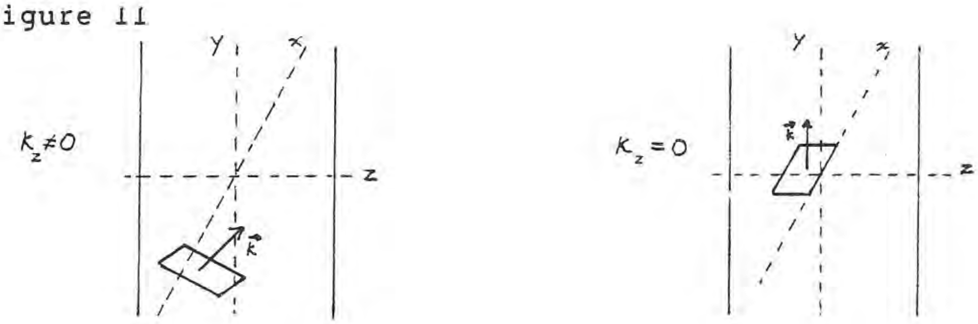
$$k_x = \frac{\pi}{L} n_x \qquad k_y = \frac{\pi}{L} n_y \qquad k_z = \frac{\pi}{a} n_z , \tag{1}$$

where n_x, n_y, n_z are positive integers. From this follows the relationship

$$k = \sqrt{(k_x^2 + k_y^2 + k_z^2)}.$$

At the boundaries the $\vec{E}$ component of the electromagnetic field in the cavity is normal to the two plates, for each plate is an equipotential surface, and the $\vec{B}$ component is parallel to the plates. If the component k_z perpendicular to the plates is different from zero, it can take discrete values given by $n_z \pi/a$; and there are two polarization states. If, however, k_z vanishes (i.e. when $n_z=0$), only one mode survives. For k_x and k_y this is of no importance since for very large L, k_x and k_y may be considered as continuous variables. That is, as $L \to \infty$, the spacing between adjacent resonance frequencies becomes very small, so for those two components $k_n \to k(n)$. This statement introduces a further idealization, viz. that our two perfectly conducting plates extend infinitely in the xy-plane.

Figure 11



(a) (b)

In figure (a) there would be polarization in all three directions,but since E=0 all along the xy plane, there is polarization only inthe x- and y-directions. In figure (b) there is no y-component of the E, so there is polarization only in the x-direction.

For the situation in which the plates are separated by a small distance a, the total energy of the cavity is given by

$$E_o = \sum_{n=1}^{\infty} \tfrac{1}{2} \hbar \omega_n , \qquad (2)$$

as we have seen before. The energy for the modes corresponding to $n_z=1$ is given by

$$\frac{1}{2}\hbar\omega_1 = \frac{1}{2}\hbar c k_1$$

$$= \frac{1}{2}\hbar c \cdot 2\int_0^\infty\int_0^\infty \sqrt{\left(\frac{\pi n_x}{L}\right)^2+\left(\frac{\pi n_y}{L}\right)^2+\left(\frac{\pi n_z}{a}\right)^2}\, dn_x\, dn_y\,, \qquad (3)$$

where n_x and n_y are integrated over all values. The factor of 2 is introduced to account for the two polarization states.

On the basis of equation (1),

$$dk_x = \frac{\pi}{L}\, dn_x \qquad dk_y = \frac{\pi}{L}\, dn_y\,. \qquad (4)$$

Thus, by a substitution of variables,

$$\frac{1}{2}\hbar\omega_1 = \hbar c\, \frac{L^2}{\pi^2}\int_0^\infty\int_0^\infty \sqrt{k_x^2 + k_y^2 + \pi^2/a^2}\;\; dk_x\, dk_y\,. \qquad (5)$$

The boundaries of integration suggest that we are integrating over the resonance requencies from zero to infinity. Now we must proceed to sum up all the energies for the modes n_z=1 up to n_z=∞:

$$\sum_{n=1}^{\infty} \frac{1}{2}\hbar\omega_n = \hbar c\, \frac{L^2}{\pi^2}\sum_{n=1}^{\infty}\int_0^\infty\int_0^\infty \sqrt{k_x^2 + k_y^2 + \frac{n_z^2\pi^2}{a^2}}\;\; dk_x\, dk_y\,. \qquad (6)$$

For the n_z=0 mode, the factor $n_z^2\ \pi^2/a^2$ drops out; and since there is now only one polarization state, the factor of 2 in equation (3) is omitted:

$$\frac{1}{2}\hbar\omega_0 = \frac{1}{2}\hbar c\, \frac{L^2}{\pi^2}\int_0^\infty\int_0^\infty \sqrt{k_x^2 + k_y^2}\;\; dk_x\, dk_y\,. \qquad (7)$$

Combining equations (6) and (7), we can calculate the total energy of the cavity for all modes from zero to infinity:

$$\sum E = \sum_{n=0}^{\infty} \frac{1}{2} \hbar\omega_n = \hbar c \frac{L^2}{\pi^2} \int_0^{\infty}\int_0^{\infty} \left[\frac{1}{2}\sqrt{k_x^2 + k_y^2} + \sum_{n_z=1}^{\infty} \sqrt{k_x^2 + k_y^2 + \frac{n_z^2 \pi^2}{a^2}} \right] dk_x\, dk_y . \quad (8)$$

This equation can be simplified by introducing polar coordinates in the $k_x k_y$ plane and defining $K^2 = k_x^2 + k_y^2$. Thus,

$$\sum E = \hbar c \frac{L^2}{\pi^2} \frac{\pi}{2} \sum_{(0)1}^{\infty} \int_0^{\infty} \sqrt{K^2 + \frac{n_z^2 \pi^2}{a^2}} \; K\, dK . \quad (9)$$

The factor of $\frac{1}{2}\pi$ is due to the fact that we are integrating only in the first quadrant, for positive values of $k_x k_y$. The notation (0)1 is shorthand to indicate that the term with $n_z = 0$ has to be multiplied by $\frac{1}{2}$.

In the second situation proposed by Casimir, when the distance between the plates is very large, the exceptional status of the k_z terms in the above equations disappears. This introduces the element dn_z, which yields by substitution the factor $a\,dk_z/\pi$. Thus, for large a the total energy of the cavity is given by

$$\sum E = \hbar c \frac{L^2}{\pi^2} \frac{\pi}{2} \frac{a}{\pi} \int_0^{\infty}\int_0^{\infty} \sqrt{K^2 + k_z^2} \; K\, dK\, dk_z . \quad (10)$$

We are now dealing with a further idealization: a cubic cavity whose walls are all infinitely far apart. The difference between the energies in the two situations, as given in equations (9) and (10), is the interaction energy between the plates:

$$\Delta E = \hbar c \frac{L^2}{\pi^2} \frac{\pi}{2} \left\{ \sum_{(0)1}^{\infty} \int_0^{\infty} \sqrt{K^2 + \frac{n_z^2 \pi^2}{a^2}} \, K dK - \frac{a}{\pi} \int_0^{\infty}\int_0^{\infty} \sqrt{K^2 + k_z^2} \, K dK \, dk_z \right\}. \qquad (11)$$

This quantity is apparently still not defined due to ultraviolet divergences for large k. Although ideal perfectly conducting plates may be impervious to wavelengths shorter than the atomic size, such cavity walls cannot be produced in the laboratory. Actual physical plates would hardly act as an obstacle for very short waves (e.g. X-rays or shorter), so the zero-point energy of those waves would not be affected by the different positions of the plates in the two situations. In order to obtain a finite result from equation (11), Casimir uses this fact as justification for multiplying the integrands by a function $f(k/k_m)$, which is unity for $k \ll k_m$ but tends to zero sufficiently rapidly for $(k/k_m) \to \infty$. The term k_m may be defined by $f(1)=\frac{1}{2}$.

With this step we partially withdraw from our pure idealization of perfectly conducting plates of infinite dimension, infinitely far apart. We assert that actual plates which approximate that idealization would obstruct wavelengths only down to a finite size. That introduction of empirical fact relieves us of the theoretical infinity, but meanwhile we retain the other facets of our idealization; otherwise, no theoretical calculation could be made at all.

To restate the above restriction:

$$f(k/k_m)=1 \quad \text{for} \quad k/k_m \; 0$$
$$f(k/k_m)=o \quad \text{for} \quad k/k_m \; \infty \tag{12}$$

We now introduce the variable $u=a^2K^2/\pi^2$. Therefore,

$$K^2 = \frac{u\pi^2}{a^2} \qquad dK = \frac{\pi^2}{2a^2K}\,du \qquad k = \frac{\pi}{a}\sqrt{u+n_z^2} \qquad f(K/k_m) = f\left(\frac{\pi\sqrt{u+n_z^2}}{a}\Big/k_m\right) \tag{13}$$

and

$$\Delta E = \hbar c\,\frac{L^2}{\pi^2}\,\frac{\pi}{2}\left\{\sum_{(o)1}^{\infty}\int_0^{\infty}\sqrt{(n_z^2+u)\pi^2/a^2}\; f\left(\frac{\pi\sqrt{u+n_z^2}}{a k_m}\right)\frac{\pi^2}{2a^2}\,du - \int_0^{\infty}\int_0^{\infty}\sqrt{(n_z^2+u)\pi^2/a^2}\; f\left(\frac{\pi\sqrt{n_z^2+u}}{a k_m}\right)\frac{\pi^2}{2a^2}\,du\,dn_z\right\} \tag{14}$$

$$\Delta E = L^2\hbar c\,\frac{\pi^2}{4a^3}\left\{\sum_{(o)1}^{\infty}\int_0^{\infty}\sqrt{n_z^2+u}\; f\left(\frac{\pi\sqrt{n_z^2+u}}{a k_m}\right)du - \int_0^{\infty}\int_0^{\infty}\sqrt{n_z^2+u}\; f\left(\frac{\pi\sqrt{n_z^2+u}}{a k_m}\right)du\,dn_z\right\}. \tag{15}$$

We now introduce another variable $w=u+n_z^2$ and insert it in equation (15):

$$\Delta E = L^2\hbar c\,\frac{\pi^2}{4a^3}\left\{\sum_{(o)1}^{\infty} w^{1/2} f\left(\frac{\pi w^{1/2}}{a k_m}\right)dw - \int_0^{\infty}\int_0^{\infty} w^{1/2} f\left(\frac{\pi w^{1/2}}{a k_m}\right)dw\,dn_z\right\}. \tag{16}$$

We further define the quantity

$$F(n_z) = \int_{n_z^2}^{\infty} w^{1/2} f\left(\frac{\pi w^{1/2}}{a k_m}\right)dw\,, \tag{17}$$

and insert this in equation (16):

$$\Delta E = L^2 \hbar c \frac{\pi^2}{4a^3} \left\{ \sum_{(0)1}^{\infty} F(n_z) - \int_0^{\infty} F(n_z)\, dn_z \right\}. \tag{18}$$

We are now in a position to apply the Euler-Maclaurin sum formula, which states[4]:

$$\sum_{(0)1}^{\infty} F(n) - \int_0^{\infty} F(n)\, dn = -\frac{1}{2!} B_2 F'(0) - \frac{1}{4!} B_4 F'''(0) + \ldots \tag{19}$$

The Bernoulli numbers B_v are defined through the series

$$\frac{y}{e^y - 1} = \sum_{v=0}^{\infty} B_v \frac{y^v}{v!}. \tag{20}$$

For greater ease of calculation we may introduce a series expansion into equation (20):

$$\frac{1}{y}\left(y + \frac{y^2}{2!} + \frac{y^3}{3!} + \ldots \right)\left(B_0 + B_1 y + B_2 \frac{y^2}{2!} + \ldots \right) = 1 ,$$

yielding

$$\begin{array}{lll} B_0 = 1 & B_1 = -\frac{1}{2} & \\ \frac{1}{2!} B_0 + B_1 = 0 & B_2 = \frac{1}{6} & B_{2n+1} = 0 , \quad n = 1, 2, 3 \ldots \\ \frac{1}{3!} B_0 + \frac{1}{2!} B_1 + \frac{B_2}{2!} = 0 & B_4 = -\frac{1}{30} & \end{array}$$

Thus, equation (19) becomes

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[4] For a derivation of this formula see A First Course in Numerical Analysis, by Anthony Ralston and Philip Rabinowitz (McGraw-Hill Book Co., N.Y., 1978) pp. 136-8.

$$\sum_{(0)1}^{\infty} F(n) - \int_0^{\infty} F(n)\, dn = -\frac{1}{12} F'(0) + \frac{1}{24 \times 30} F'''(0) + \ldots \tag{21}$$

To compute the derivative of $F(n_z)$, we use the theorem

$$\text{For } h(x) = \int_a^x g(y)\, dy \qquad h'(x) = g(x), \tag{22}$$

where a is a constant and x is a variable. Thus, if

$$f(x) = \int_a^{x^2} g(y)\, dy, \tag{23}$$

we let $x^2=z$, such that $dx=1/2z^{\frac{1}{2}}$, and

$$f(z^{1/2}) = \int_a^z g(y)\, dy. \tag{24}$$

Then

$$\frac{d}{dx} f(x) = \frac{d}{d(z^{1/2})} f(z^{1/2}) = \frac{1}{2z^{1/2}} f'(z^{1/2}) = \frac{1}{2x} f'(x). \tag{25}$$

It then follows that

$$f'(x) = 2x \frac{d}{dz} \int_a^z g(y)\, dy = 2x\, g(z) \tag{26}$$

from the theorem of equation (22), and thus

$$f'(x)=2x\ g(x^2) \tag{27}$$

To apply equation (23) to $F(n_z)$, we reverse the boundaries of integration:

$$F(n_z) = -\int_{\infty}^{n_z^2} w^{1/2} f\left(\frac{\pi w^{1/2}}{a k_m}\right) dw. \tag{28}$$

Since the lower boundary of integration is not a variable, it drops out of any derivatives of $F(n_z)$, so it is of no significance for our purposes that it is infinite. Applying equation (27) to (28) yields the result

$$\begin{aligned} F'(n_z) &= -2n_z \sqrt{n_z^2}\, f\left(\frac{\pi\sqrt{n_z^2}}{a k_m}\right) \\ F'(n_z) &= -2n_z^2 f\left(\frac{\pi n_z}{a k_m}\right) \\ F'(0) &= 0. \end{aligned} \tag{29}$$

Then

$$\begin{aligned} F''(n_z) &= -4n_z f\left(\frac{\pi n_z}{a k_m}\right) - 2n_z^2 \frac{df}{dn_z}\left(\frac{\pi n_z}{a k_m}\right) \\ F'''(n_z) &= -4 f\left(\frac{\pi n_z}{a k_m}\right) - 4n_z f\left(\frac{\pi n_z}{a k_m}\right) - 4n_z \frac{df}{dn_z}\left(\frac{\pi n_z}{a k_m}\right) - 2n_z^2 \frac{d^2 f}{dn_z^2}\left(\frac{\pi n_z}{a k_m}\right) \\ F'''(0) &= -4f(0) \\ F'''(0) &= -4\,. \end{aligned} \tag{30}$$

The identity in equation (30) depends upon the stipulation in equation (12). The higher derivative of $F(n_z)$ will contain powers of π/ak_m, so a good approximation can be obtained while ignoring them, as long as $ak_m \gg 1$.

By inserting the values of equations (29) and (30) into (21) and applying this to equation (16) we find the result

$$\Delta E = -L^2 \hbar c \pi^2 \frac{1}{720} \frac{1}{a^3}\,. \tag{31}$$

The interaction energy per unit area of the plates would therefore be

$$\frac{\Delta E}{L^2} - \frac{\hbar c \pi^2}{720}\frac{1}{a^3}\,. \tag{32}$$

Taking the negative of the derivative of this potential energy yields the interacting force per unit area:

$$\frac{F}{L^2} = -\frac{\hbar c \pi^2}{240}\frac{1}{a^4} = -0.013\frac{1}{a_{\mu}^4}\frac{dyne}{cm^2}\,, \tag{33}$$

where a_{μ} is the distance in microns, and the sign corresponds to attraction.

The fact that the force per unit area is proportional to $\hbar c/a^4$ could have been predicted by means of dimensional analysis. It must have the dimension $ML^{-1}T^{-2}$ (where M is mass, L length and T time). The only quantities entering the problem are $\hbar$, c and the separation a. The force, like the zero-point energy must be proportional to $\hbar$; and given those conditions, $\hbar c/a^4$ is the only quantity with the required dimension.

The above calculations indicate that an attractive force exists between two metal plates which is independent of the material of the plates, with one stipulation: When the distance between them is comparable to the wavelengths, the penetration depth must be small compared with that distance.

This force may be interpreted as a zero-point pressure of electromagnetic waves in a vacuum. Although the above derivation disregards the effects outside the plates, in the present case they turn out to cancel exactly. While acknowledging that the effect of this pressure is small, Casimir suggests that an experimental confirmation may be feasible. In their textbook on quantum field theory Itzykson and Zuber declare that both its magnitude and its dependence on the interplate distance were indeed demonstrated experimentally by Sparnaay in 1958.[5] Thus, that experiment deserves our careful scrutiny.

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[5] Quantum Field Theory, by Claude Itzykson and Jean-Bernard Zuber (McGraw-Hill Book Co., N.Y., 1980) p. 141.

APPENDIX III:

THE CASIMIR EFFECT PUT TO EXPERIMENT

In the year 1958, M.J. Sparnaay presented a paper entitled "Measurements of attractive forces between flat plates," which sets forth his empirical test of Casimir's theoretical prediction.[1] In the abstract of his discussion he declares that the observed attractive forces between flat metal plates "do not contradict" that prediction. In reviewing this experiment, we shall try to determine whether he in fact confirmed it.[2]

Sparnaay reiterates Casimir's stipulation that the latter's prediction should hold only if the distance between plates is larger than the penetration depth of the electromagnetic waves in the metal. Sparnaay estimates that depth to be of the order of 0.1 micron. If that distance is shorter than the penetration depth, Casimir's equation,

$$F = \frac{0.013}{d^4} \frac{dyne}{cm^2} , \qquad (1)$$

[1] Sparnaay, M.J., Physica 24 (1958) 751.

[2] Note that Aitchison (1985, p. 343) also claims that Sparnaay demonstrated the existence of the tiny zero-point force predicted by Casimir.

reduces to the Hamaker-De Boer equation, which is based on the existence of London-Van der Waals forces between the atoms in both plates.[3] Sparnaay gives this equation in the form:

$$F = \frac{A}{6\pi} \frac{1}{d^3} . \qquad (2)$$

For plates of identical material the constant $A=\pi q^2\lambda$, where q is the number of atoms per cm^3 of the plate material and, according to London's harmonic oscillator model[4], $\lambda=\frac{4}{3}\alpha h\nu/3$, where α is the polarizability of an atom and $h\nu$ is its ionization energy. That expression assumes that the London-Van der Waals forces are additive. Sparnaay reports that for most materials the value of $A/6\pi$ may be estimated to be between 0.02 and 0.4. (while d is again expressed in microns and F in $dynes/cm^2$).

The Plates

In choosing the plate material, Sparnaay had to meet three requirements:

(1) Obstacles on the plates, larger than 0.5 micron had to be removed.

(2) Static electric charges on the plates should be absent, or, where present, their influence should be excluded.

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[3] Hamaker, H.C., Physica 4 (1937) 1058.

[4] London, F., Z. physik Chemie B 11 (1931) 222.

(3) The influence of differences of surface potentials on both plates should be eliminated.

Apart from dirt specks, an oxide layer may appear on the surface of a metal due to atmospheric influences. On chromium steel and chromium, this layer has a thickness of only 5-50 Å. Moreover, those two materials are very hard, and their surfaces could be lapped sufficiently flat that the maximum protrusions were less than 500 Å. Thus, in this experiment Sparnaay used two chromium steel plates and two chromium plates. He also used aluminum plates, but the forces between them turned out to be repulsive (instead of attractive, as predicted by Casimir). We shall therefore ignore that part of the experiment, whose aberration was possibly due to an oxide layer on the plates.

Static electric charges on the plates are a serious problem when their surfaces are of an insulating material, but in this case conducting plates were used. In order to prevent a difference of surface potentials on both surfaces, Sparnaay took steps to ensure that the atmosphere between the plates should not be made conductive. The metal plates were also rigidly insulated.

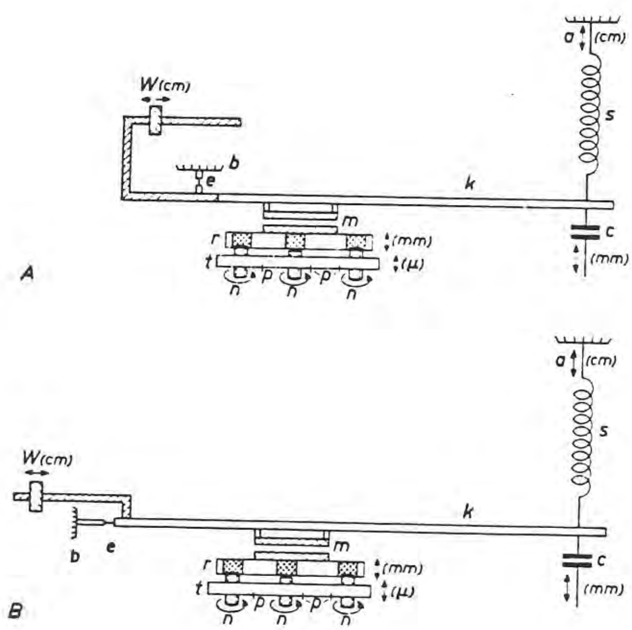
The Apparatus

The metal plates, of area 1 cm^2, used by Sparnaay were placed in a glass cylinder of radius 15 cm and height 30 cm.

It could be closed at both sides by steel plates. After replacing the atmosphere by pure, dust-free nitrogen gas, the system was usually evacuated until a pressure, not lower than 10^{-2}mm Hg was obtained. This should be viewed in light of a high vacuum with a pressure of 10^{-6} mm Hg, and an ultrahigh vacuum of 10^{-10} mm Hg, which can be created now with modern technology.

Although the apparatus was placed on a relatively vibration-free table, small anharmonic vibrations were nevertheless observed. Sparnaay was able to suppress these somewhat, but they remained as a factor limiting the accuracy of the measurements. Thus, when the plates were relatively far apart (2 microns), the sensitivity was only about 1×10^{-3} dyne. At closer distances he was able to obtain a sensitivity up to 0.1×10^{-3} dyne.

Figure I



Two types of balance systems used by Sparnaay are shown schematically in Figure I.[5] That attraction between the metal

plates m when the interplate distance was made sufficiently small gave rise to a deflection of the aluminum beam k. This deflection was measured by an increase of the capacity of the condenser c. At the left-hand side of the suspension e the copperbodies W, one at each side of e, nearly counterbalanced the weight of the upper plate m. To attain equilibrium of the balance, the weight and location of the copperbodies could be varied, as could the point of vertical suspension of the spring s. The force constant of the whole balance sustem was made between 10-100 dyne/cm. Since a distance variation of 100 Å was detectable, the force sensitivity was up to 10^{-5} dyne. A detection of lower force values was prevented by the presence of anharmonic vibrations.

The lower metal plate m was mounted on the brass plate r, which in turn was mounted rigidly on a "kinematic mount," so that it was not overly constrained. This allows for expansion with the least possible fixation in space. Both the metal plate and its brass support were insulated. The upper plate m was fixed, and the position of the lower plate was adjusted with an intricate lever system. When the

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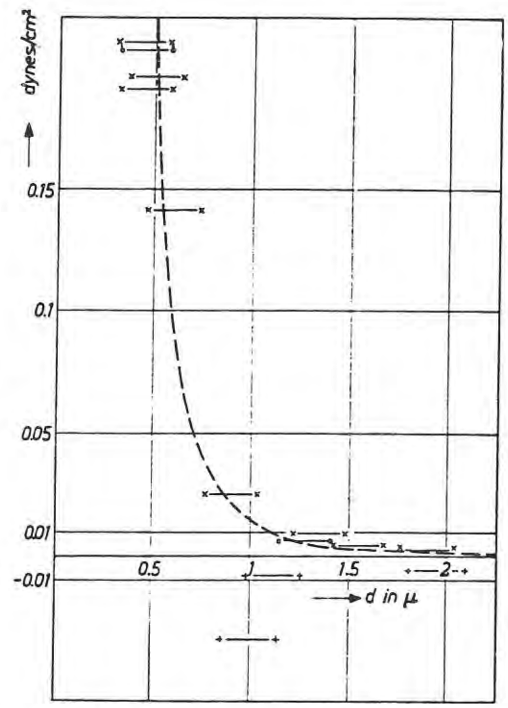
[5] Reprinted by from Sparnaay's paper with permission from the author.

average interplate distance was about 5 microns, the difference between the minimum and maximum distance could be made 0.4 ± 0.1 micron. There probably existed relative deflections of the planes of the plate surfaces of about 0.2 micron, mainly due to dust particles. Since such particles could settle at any moment, experiments were preferably made as short as possible after a fairly parallel position was obtained.

The Measurements

Sparnaay's results are shown in Figure II[6]. The dotted line corresponds to Casimir's prediction (equation (1)), the horizontal lines show the uncertainty of the distance between the plates, the diagonal crosses are for the chromium steel plates, and the circles are for the chromium plates. The vertical crosses indicate the repulsive forces measured between aluminum plates.

Figure II



Only effects that occurred instantaneously (i.e. in less than ½ minute) upon decreasing or increasing d were considered. Sparnaay points out that the results of the first two of these metals do not deviate seriously from

[6]Reprinted by request from Sparnaay's paper.

Casimir's predictions, though the attractions found are somewhat too large. Whereas the attraction was strong at 0.3-0.5 micron, no effect at all could could be detected at a distance of 2.5 microns. It must be emphasized that the magnitude of the measured force in this experiment is very small: roughly ten times the weight of a red blood cell.

An experimental test of Casimir's prediction must clearly determine two things: (1) the magnitude of the force, and (2) the relationship between the force and the distance between the plates. A confirmation of the Casimir effect must demonstrate that the coefficient of magnitude more closely approximates 0.013 [in equation (1)] for the zero-point force as opposed to the range 0.02-0.4 for the unretarded London-Van der Waals force. And it must demonstrate that the force is an inverse fourth-power (as predicted for the zero-point force) and not an inverse-cube attraction (as predicted for the London-van der Waals force).

Sparnaay does not give a numerical table of his data, nor does he provide a log-log graph of the data, which would be one way of determining the dependence of the force on the interplate distance.

The table of data here has been drawn from his graph in Figure II, and Figure III presents a log-log graph of that data. On the basis of equations (1) and (2) it follows that the log of the force equals the log of the coefficient of magnitude plus the log of the inverse of the fourth and third power of the distance respectively. Thus, the measured coefficient of magnitude can be determined on the basis of the y-intercept of the log-log graph, where the log value associated with distance equals zero. The value of that coefficient is determined by taking the antilog of the value at that y-intercept. It is found to be 0.02, a value at the low end of the range of coefficients for the London-Van der Waals force, as opposed to the coefficient for the zero-point force. The median slope of the log-log graph of the data indicates almost precisely an inverse-cube force law. Thus, although the data points do not radically deviate from Casimir's predictions, they hardly confirm the prediction of an inverse fourth-power force law.

In short, Sparnaay demonstrated neither the magnitude of the zero-point force nor its dependence on the interplate distance--contrary to the report of Itzykson and Zuber.[7] His work rather indicates both the magnitude of the ordinary (unretarded) London-Van der Waals force and its inverse-cubic dependence on the interplate distance.

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[7] Quantum Field Theory, C. Itzykson and J. Zuber (McGraw-Hill Book Co., N.Y., 1980) p. 141.

Data for chromium steel plates

Minimum d (microns)	Maximum d (microns)	Median d (microns)	Force (dynes/cm)
0.31	0.58	0.45	0.211
0.38	0.65	0.52	0.195
0.31	0.58	0.45	0.191
0.46	0.73	0.60	0.141
0.77	1.04	0.91	0.025
1.23	1.50	1.37	0.010
1.42	1.69	1.56	0.005
1.77	2.04	1.91	0.003

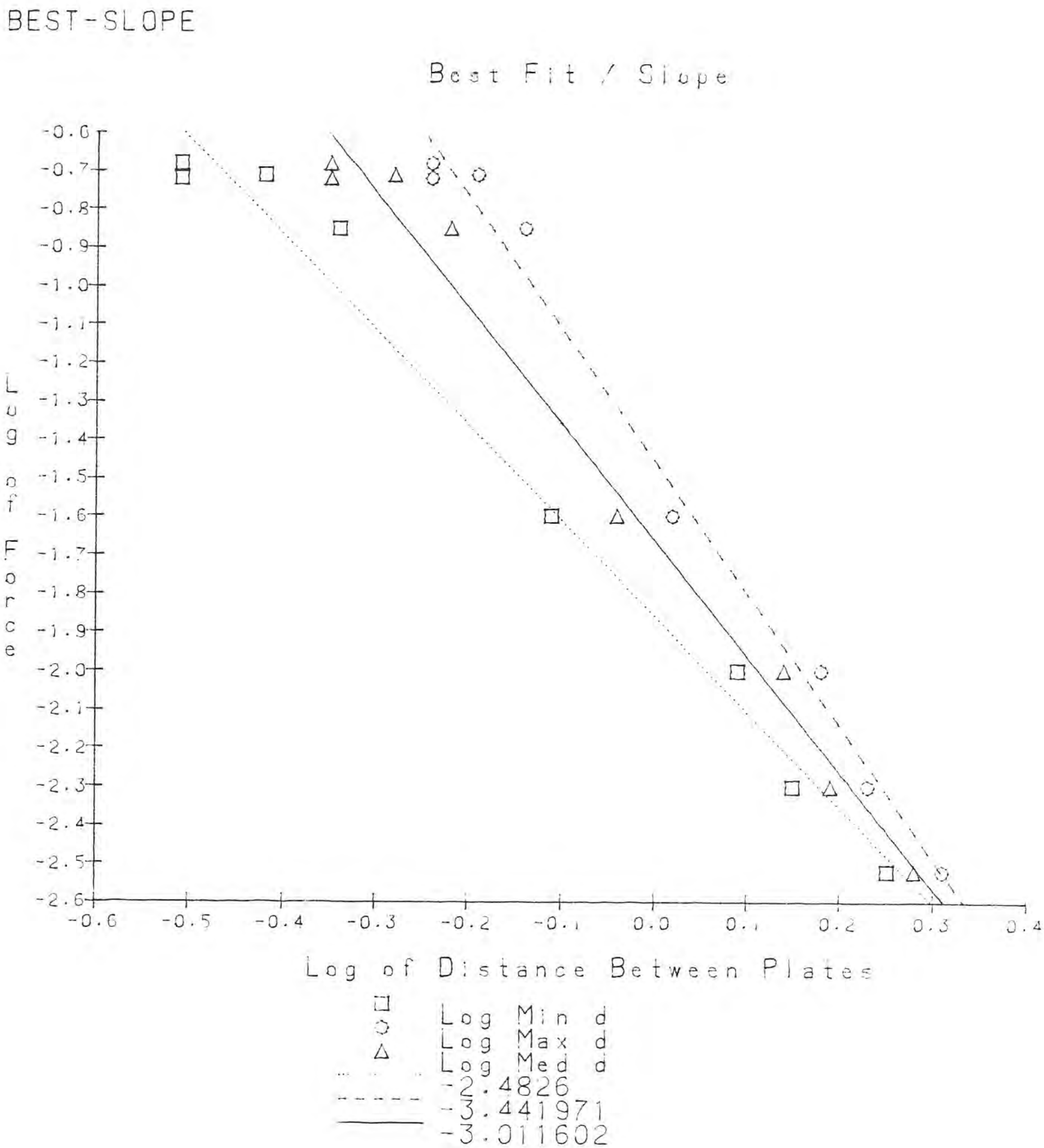
Log min d	Log max d	Log med d	Log F
-0.51	-0.24	-0.35	-0.68
-0.42	-0.19	-0.28	-0.71
-0.51	-0.24	-0.35	-0.72
-0.34	-0.14	-0.22	-0.85
-0.11	0.02	-0.04	-1.60
0.09	0.18	0.14	-2.00
0.15	0.23	0.19	-2.30
0.25	0.31	0.28	-2.52

Minimum slope = -2.48

Maximum slope = -3.44

Median slope = -3.01

Figure III


BEST-SLOPE
Best Fit / Slope
Log of Force
Log of Distance Between Plates
-0.6
-0.7
-0.8
-0.9
-1.0
-1.1
-1.2
-1.3
-1.4
-1.5
-1.6
-1.7
-1.8
-1.9
-2.0
-2.1
-2.2
-2.3
-2.4
-2.5
-2.6
-0.6
-0.5
-0.4
-0.3
-0.2
-0.1
0.0
0.1
0.2
0.3
0.4
Log Min d
Log Max d
Log Med d
-2.4826
-3.441971
-3.011602