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Religion, Philosophy, and the Second Law of Thermodynamics

Carter Braxton Finn
College of William & Mary - Arts & Sciences

RELIGION, PHILOSOPHY, AND THE SECOND LAW OF THERMODYNAMICS

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This thesis is submitted in partial fulfillment of the requirements for the degree of

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Vernon H. Edmonds

Edwin H. Rhyne

Michael A. Faia

Thomas Christ

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ABSTRACT

The first and second laws of thermodynamics, stating respectively the conservation and the dissipation of energy, are considered by many writers to be the two most fundamental laws of the universe. Both laws are held to be empirically derived. Yet, upon reflection, it does not seem possible to state, from the limited empiric evidence available, either proposition as a universal law. A further element appears to be involved in such statement: philosophical and religious belief. In this paper the conservation law is traced to its origins in Greek philosophy. The second law is traced to its origins in the traditional Christian outlook. Traditional Christian concepts appear to have deeply influenced many of the scientists who stated and developed the second law as a universal principle. To cite Lord Kelvin (William Thomson), one of the originators of the second law, the law meant that ". . . all motion except that of heat must have an end, unless it please God to restore by an act of new creative power the dissipation of mechanical effect that always goes on."

The conceptual development of the second law is followed from the works of Newton through the treatments of Laplace, Whewell, Kelvin, Clausius, Maxwell, Tyndall, Stewart and Tait, Clifford, Boltzmann, Planck, Jeans, Eddington, Whitehead, and a number of other wirters. The view of these writers on the objective truth or falsity of the second law as a universal principle is found to vary less with empiric evidence than with philosophical and religious belief.

From the thoughts of certain of these men, it is suggested that the physical evidence taken as supporting the second law (which states that entropy can remain constant or increase, but can never decrease) may, when considered with Newton's third law of motion (for every action there is an equal and opposite reaction) suggest the probable presence of generically different, and counterbalancing phenomena, yet to be discovered. A full statement of the second law may turn out to be entropy-symmetrical.

This theoretical possibility holds strong implications for technology. For over a hundred years, we have employed a dissipative technology of low efficiency, which embodies our understanding of the second law. We have, as a result, an ecological and energy crisis. If entropy changes turn out to be symmetrical for the universe as a whole, there may well be no ultimate barrier to the development of a technology which closely approaches unity in its efficiency. Re-examination of the second law, with a view to obtaining higher technological efficiency, is urged. The thoughts of many of the writers, particularly the physicists, appear seminal in this regard.

RELIGION, PHILOSOPHY, AND THE SECOND LAW OF THERMODYNAMICS

Would you that spangle of Existence spend
About THE SECRET -- quick about it, Friend!
    A Hair, they say, divides the False and True --
And upon what, prithee, does Life depend?

A Hair, they say, divides the False and True;
Yes; and a single Alif were the clue --
    Could you but find it, to the Treasure-house,
And peradventure to THE MASTER too;

Whose secret Presence, through Creation's veins
Running, Quicksilver-like eludes your pains;
    Taking all shapes from Mah to Mahi; and
They change and perish all -- but He remains;

A moment guess'd -- then back behind the Fold
Immerst of Darkness round the Drama roll'd
    Which, for the Pastime of Eternity,
He does Himself contrive, enact, behold.

--Rubaiyat of Omar Khayyam

INTRODUCTION

This thesis is an historically oriented essay in the sociology of scientific knowledge. It examines the growth and cosmological application of the second law of thermodynamics from the nineteenth century to the present time, through the study of the thoughts of twelve men[1] who have contributed to the dialogue which shaped the second law. The nineteenth century is the primary period of focus.

A number of factors underlie the development of the second law. Many of them may be grouped under the three following categories: empiric, theoretic, and social (philosophic and religious). Let us consider, in an introductory way, each category in turn.

Empiric Factors

The second law was derived, empirically, from a macroscopic study of energy transformations. In the 1840's particular attention had been focused on the convertibility of one form of energy into another, and the first law of thermodynamics, postulating the conservation of energy, was publicly announced by Meyer, J.P. Joule, Colding and Helmholtz. The second law was developed very soon thereafter. In the study of conversion processes, it was observed that electrical, chemical, mechanical and other forms of energy tended to become transformed into the type of

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[1]William Thomson (Lord Kelvin), L. Boltzmann, J.C. Maxwell, J. Tyndall, W.K. Clifford, the Rev. Wm. Whewell, P.G. Tait, B. Stewart, Max Planck, Sir James Jeans, Sir Arthur Eddington, and Phillip Frank. The thoughts of a number of other men are considered less centrally.

energy known as heat. Heat in turn tended to flow spontaneously from hotter to colder bodies in thermal contact, but the reverse process, a flow of heat from a colder to a hotter body, was not observed to occur of itself. As Max Planck (1949:17) has noted: "Clausius deduced his proof of the second law of thermodynamics from the hypothesis that 'heat will not pass spontaneously from a colder to a hotter body.'" A heat flow from a hotter to a colder body continues until all parts of the thermal system are at the same temperature. At such time observable heat flow ceases and, if the system is isolated from other influences, it becomes thermodynamically quiescent. A similar process is displayed in gas and liquid diffusion, and pressure equalization. The quiescent state of a system is termed thermodynamic equilibrium. All isolated systems observed to date move toward equilibrium, and classical thermodynamics assumes that all systems will exemplify this tendency (Callen, 1960).[2]

The above elements provide the basis for the second law as an engineering principle. Sadi Carnot (1796-1832) developed, from an analysis of the flow of heat, a conceptual model wherein the upper limit of efficiency of an ideal, cyclical heat engine could be calculated. The engine was composed of an ideal cylinder and piston, with a gas inside which expanded when heated and contracted when cooled, moving the piston in the process. To extract mechanical work from heat, the cyclically operating working fluid or gas within the engine had to be alternately placed in thermal contact with (a) a heat source at some temperature T_1,

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[2]With respect to the movement of an isolated system to thermodynamic equilibrium, Callen (1960:24) comments: "The basic problem of thermodynamics is the determination of the equilibrium state that eventually results after the removal of internal constraints in a closed composite system."

which it took heat energy from, and then, (b) a heat sink at some lower temperature T_2, to which it exhausted heat energy not transformed to work. The Carnot relationship indicates that a heat engine will not operate in a continuous cyclical fashion when the heat source and the sink are at the same temperature. Conversely, given a heat source at any temperature above absolute zero and a sink at absolute zero, thermodynamic efficiency may in the ideal case approach unity. As a matter of experience, a corollary was added to the effect that a heat sink at absolute zero (-273 degrees centigrade) was unobtainable. Thus no heat engine, even in the ideal case, could be completely efficient, and could not be a perpetual motion machine of the second category (cf. Feynman, Leighton, and Sands, 1963).[3]

In the 1850's William Thomson (Lord Kelvin) in England and Rudolph Clausius in Germany, developing upon the lines of thought and evidence mentioned above, independently announced statements of the second law of thermodynamics.[4] Theoretically, the second law was stated in terms of macroscopic parameters such as temperature, pressure, volume, and so forth. This form of the law has come to be called the classical statement of the second law. The gist of Kelvin's statement is that energy tends to become dissipated, or unavailable in transformations; Clausius gave the concept (and term) entropy as a measure of the

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[3]On page 44-10 Feynman comments, while considering the efficiency of the Carnot heat engine, "The efficiency cannot be greater than unity and the absolute temperature cannot be less than zero, absolute zero. So, since T_2 must be positive, the efficiency is always less than unity. That is our first conclusion."

[4]In "The Dynamic Theory of Heat," (R. S. Edinburgh, March 17, 1851, xx p. 265) Kelvin stated, "It is impossible, by means of inanimate physical agency, to derive mechanical effect from any portion of matter by cooling it below the temperature of the coldest of the surrounding objects." Clausius' statements were of a similar import.

unavailable energy in a system. In the formulations of both men, available energy tended to become unavailable, while unavailable energy never tended of itself to become available again. When applied to the universe, these ideas lead to the presumption that the universe, like Carnot's heat engine, can never be a 'perpetuum mobile' of the second category.

Theoretic Factors

Theoretically, two major approaches may be taken to the phenomena which empirically underlie the second law. The route which deals with macroscopic variables is the first that historically developed; as noted, it is called the classical approach. The second route involves application of statistical and mechanical assumptions to a kinetic-atomic model of the macroscopic phenomena. In the kinetic-atomic model the large-scale phenomena such as temperature, pressure, etc., are related to the mass, number, velocity, and other "workings" of molecules or atoms. The kinetic approach may be characterized as the explanation of visible phenomena from the standpoint of microscopic matter in motion. This latter approach was proposed and developed at a time when atoms were not yet empirically known to exist. Kelvin, Clausius, Maxwell, Tait, Boltzmann, Loschmidt, and a number of others developed this approach throughout the second half of the nineteenth century.

The kinetic, statistical-mechanical approach suggests somewhat different conclusions about entropy and thermodynamic equilibrium than the conslusions suggested by the classical approach (cf. Frank, 1946:19-34). In the classical approach, entropy should not, assuming the absence of a source of heat generation other than heat itself, ever decrease; and isolated or contained systems, once in thermodynamic equilibrium, should not of themselves leave that state to become once again active. On the other hand, the reversible assumptions of the statistical-mechanical kinetic approach do not rule this possibility out. They further contain the definite, calculable (and verified) prediction that the microscopic parts, or molecules of a gas in macroscopic equilibrium at a single temperature, are continually departing from and returning to the average values reflective of the macroscopic equilibrium. Kinetic theory carried with it, in addition, certain of the presumptions of atomistic philosophy, specifically, that the atoms of which observable phenomena were comprised remain indestructible, unbroken and unworn. In a word, atoms were conserved. Today we know that matter can be transformed into energy. However, the principle of the conservation of energy continues in a more general form the old assumption of the conservation or indestructibility of atoms.

In brief, two distinct views arise from the two theoretical outlooks. In the classical view isolated systems always tend to evolve toward thermodynamic inertia or 'death'; in the kinetic view such a system may, given sufficient time, spring to action once again, even though the statistical odds against its doing so may be multitillions to one (Eddington, 1959:62). Just give it time.

Time brings us to the domain of cosmology. Cosmology is a study of the universe as a whole, and such study involves great magnitudes of matter, space, and time. There does not exist as yet, and there may never exist, a body of physical knowledge sufficient to construct a definitive model of the universe. What was the universe like in the very distant past? what will it be like in the far future? Was it created, or is it uncreated? is it eternal, or not? Is its order inherent and permanent, or has that order been impressed from without by an unknown agent or process? If the latter is the case, is the universe now losing its order -- its organization? These and like questions have occurred to men since the time of the Greek philosophers. They are scientifically fascinating and still far from being answered. Modern cosmology embodies these and more recent questions in its models of the universe. Generally speaking the modern models are of two different types. On the one hand there are steady-state, oscillating and cyclical models. These models suggest that the universe may be uncreated, temporally eternal, with its order inherent and permanent. On the other hand, there are the one-time "big bang" and expanding universe theories. These contain the presumption that the "bang" and the expansion are one-shot, linear, and never-recurring. These theories imply that the universe was either created or had its initial order impressed upon it by an agent or process from without, or at least not now acting.

These two general types of models were advanced by nineteenth century thermodynamics as follows: (1) In the classical thermodynamic view, the universe had an "origin" in a state of minimal entropy at a not infinitely remote time past. It has been proceeding ever since to "run down" toward a time in the remote future when it shall, like all other isolated systems, come to rest in final thermodynamic equilibrium. Speaking from the standpoint of statistical mechanics, it shall have lost its large-scale organization, its order. And thus the universe shall sit, its energy undestroyed but self-cancelling, throughout all future eternity -- in what is termed the "heat death." (2) On the other hand, the assumptions of kinetic theory do not rule out the possibility that the universe _might_, after a sufficient number of eons in the "heat death" phase, undergo in whole or in part a fluctuation that would render it active again. Ludwig Boltzmann suggested such a 'fluctuating' model of the universe. Kelvin and others suggested the one-way, entropy increasing, ultimately 'dying' model of the universe. Each model has its strengths and weaknesses; neither is finally conclusive. The model based on classical thermodynamics and extended to the universe has had the benefit of much supporting evidence insofar as processes on earth go, and more recent discoveries also appear supportive. Two of the more recent discoveries are (a) that the universe appears to be expanding, and (b) that mass can be converted to energy. While both processes may be reversible, they have been looked upon by certain writers as irreversible, and presented as further evidence tending to confirm the classical 'heat death' model of the universe. The cosmological models of Sir James Jeans and Sir Arthur Eddington, which we shall look at in Chapter 2, are examples of this interpretation. Still, the cosmological questions remain quite unsettled. Oscillating and steady-state models of the universe have kept theoretic pace with the model of the universe based on classical thermodynamics,[5] and these models remain most consistent with the assumptions of kinetic theory.

From the 1850's until quite recently, the proponents of kinetic theory have been in a peculiar position with respect to the cyclical or oscillating models of the universe which appear possible under the assumption of kinetic theory. The kinetic approach, which envisions matter and energy in an eternal and untiring interplay between states of potential and states of motion, characterized by unbroken continuity and overall symmetry, offers logically taut and consistent assumptions, but

[5]For a good recent discussion of the present state of oscillating, steady-state and one-shot 'big bang' models of the universe, see Nigel Calder's Violent Universe (1969), Chapters III and IV.

until recently, no commanding evidence to point to with respect to its possible predictions about a self-sustaining universe.

Several interpretations of relativity theory have been made which are consistent with the assumptions of kinetic theory. Sir William C. Dampier (1949:451) has commented:

> It has been suggested that our present thermodynamics may be a peculiarity of an expanding universe; indeed Tolman has formulated a scheme of relativistic thermodynamics in which the second law is reversed in a contracting universe. Energy would then become more and more available, and the re-formulation of matter from radiation would be possible. On these lines we may speculate about a pulsating universe, in which we chance to be living in a phase of expansion, and need not contemplate a beginning or an end.

Still, such lines of thought have remained theoretical, in Dampier's wording, "speculative." The fluctuation predictions of kinetic and statistical theory have needed some large-scale evidence, for although small statistical fluctuations from maximum entropy and 'dead-level' equilibrium in small systems have been observed, no one has observed anything remotely like a fluctuation which could affect the state of the universe. That is, until recently.

Within the past few years, John Wheeler (1973), Remo Ruffini (1971), and others (Penrose, 1972), starting from certain of the predictions of relativity theory, have developed a theory of what is termed a 'black hole.' A black hole is rather like a star running in reverse. Instead of giving out radiant energy and a certain amount of mass, it 'sucks up' radiant energy and mass, and concentrates it to a state of unbelievably high density, squeezing out even the space between the subatomic particles inside it. In their description of the black hole, Ruffini and Wheeler (1971:32-33) comment:

> . . . How the physics of a black hole looks depends more upon an act of choice by the observer himself than anything else. Suppose he decides to follow the collapsing matter through its collapse

> down the black hole. Then he will see it crushed to indefinitely high density, and he himself will be torn apart eventually by indefinitely increasing tidal forces. No restraining force whatsoever has the power to hold him away from this catastrophe, once he crossed a certain critical surface known as the "horizon." The final collapse occurs a finite time after the passage of this surface, but it is inevitable. Time and space are interchanged inside a black hole in an unusual way; the direction of increasing proper time for the observer is the direction of decreasing values of the coordinate r. . . .
>
> Suppose the observer decides instead to observe the collapse from far away. Then, as the price for his own safety, he is deprived of any chance to see more than the first steps on the way to collapse. All signals and all information from the later phases of collapse never escape; they are caught up in the collapse of the geometry itself . . . a spherical system appears black from outside; no light can escape. Light shot at it falls in. A particle shot at it falls in. A "meter stick" would be let down in vain to measure the dimensions of the object. The stick is pulled to pieces by tidal forces, and the broken-off pieces fall in without a trace. In these senses the system is a black hole. . . .

The black hole is black because nothing radiates out from it. It does, however, exert gravitational force on distant objects. It is known that gravity attracts light, and a mass with sufficient gravitational force to attract and keep light -- is "black". A mechanism for the re-emergence of matter and energy from a black hole is not as yet known, but the black hole _may_ constitute a macroscopic, de-entropizing force, reconcentrating both mass and radiant energy, whose presence in the reaches of space will be significant for the predictions of kinetic theory. Considering the Carnot relationship, the matter may be expressed in the following way. The Carnot relation states, in strictness, the conditions under which the efficiency of an ideal heat engine may vary between zero and unity. It is the additional assumption that one cannot obtain a heat sink at absolute zero which, together with the Carnot relation, appears to forbid an ideal efficiency of unity. It would appear that the black hole may meet this latter criterion. From the outside, the black hole is equivalent to a sink at absolute zero. Might the universe as a whole turn out to be an 'ideal heat engine' -- a perpetuum mobile of the second category? It might, if the 'black hole' re-expands under appropriate conditions. A black hole appears to have been located in the double-star system Cygnus X1 (The Daily Press, Nov. 29, 1973:25),[6] and a good deal of theoretical consideration is going on, consideration which reflects back on the classical statement of the second law. As Nigel Calder (1969:134) has commented:

> For a hundred years physicists have believed, on very strong evidence, that the universe must always tend to become increasingly disordered. Whatever its overall architecture may be, the principle in question is the second law of thermodynamics which says the universe must grow tepid. Yet an oscillating universe is reheated and reorganized; it seems to have a fresh start every 80 billion years or so, when the accumulated debt of disorder is cancelled.

These recent developments in astrophysics are relevant to and reopen the earlier cosmological debates upon which this paper focuses. Out of the early thoughts on the second law expressed by Kelvin, Maxwell, Clifford, Boltzmann and others came the two types of models of the universe -- the cyclical or oscillating universe, eternal in time, and the temporally finite universe, with its past 'creation', and linear approach to thermodynamic 'heat death.' Only, the 'heat death' model was almost completely dominant. The other model sat on the shelf. Now matters appear to be taking on a different hue.

Even before the rapid development of 'black hole' theory in the latter part of the 60's, a shift away from the classical thermodynamic model appears evident in the thought of some writers. Reflecting on a science of thermodynamics seen by many writers in the first part of the

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[6] The article begins: "Three teams of scientists report firm evidence on the revolutionary theory that distant space contains 'black holes.'"

twentieth century to be complete in its major formulations, Percy W. Bridgman (1961:6) commented:

> Thermodynamics gives me two strong impressions: first of a subject not yet complete or at least of one whose ultimate possibilities have not yet been explored, so that perhaps there may be still further generalizations awaiting discovery; and secondly and even more strongly as a subject whose fundamental and elementary operations have never been subject to an adequate analysis.

Social Factors

In his biographical sketch of Clausius (1964), Isaac Asimov (1964: 290) comments on the 'heat death' model in cosmology in the following way:

> This dramatic picture of the end of all things has been called "the heat-death of the universe." It was a scientific analog of the Last Judgment but its validity is less certain now than it was a century ago. Though the laws of thermodynamics stand as firmly as ever, cosmologists are far less certain that the laws, as deduced in this small segment of the universe, necessarily apply to the universe as a whole and there is a certain willingness to suspend judgment on the matter of the heat-death.

Asimov's comment that the 'heat-death' theory "was a scientific analog of the Last Judgment" is particularly suggestive of the major question which we shall ask in this study. Asimov's point brings us to the social factors mentioned earlier and poses a question -- was the widespread acceptance of the heat-death hypothesis generated by facts and logic alone, or was its acceptance also aided by motivational and conceptual sets deriving from philosophy and religion?

More specifically, with respect to the social factors, the focal question of this study is, Did prior religious and philosophical conviction, deriving from traditional Christian cosmology, play a role in the generalization of the classical statement of the second law of thermodynamics from an engineering principle applying to certain phenomena, into a cosmological principle applying to the entire universe?

In light of the portrait of science as an activity which is given by most modern textbooks, this may seem at first blush to be 'merely' an historical question. The typical textbook image of science is that of a predominantly cumulative body of factual knowledge produced by men sharing a similar goal -- the theoretical description of natural processes -- no more, and no less. Nothing but "evidence" counts. Philosophical and religious elements are usually presented as historical 'sidelights' if they are presented at all. Yet, this portrait of science may not be completely accurate. Commenting on the textbook image of science, Thomas Kuhn (1970:1) states:

> That image has previously been drawn, even by scientists themselves, mainly from the study of finished scientific achievements as these are recorded in the classics, and more recently, in the textbooks from which each new scientific generation learns to practice its trade. Inevitably, however, the aim of such books is persuasive and pedagogic; a concept of science drawn from them is no more likely to fit the enterprise that produced them than an image of a national culture drawn from a tourist brochure or a language text. A . . . quite different concept of science . . . can emerge from the historical record of the research activity itself.

The historical records read in connection with research on this thesis do not fit the textbook portrait of science. Rather, they suggest a model of science -- at least the science of the period we shall look at -- best characterized as 'doing one's damdest with one's mind, no holds barred;' the holds employed being full-bloodedly philosophical and religious as well as empiric. Virtually all the men whose thought we shall consider received a classical education, which focused upon the ideas of the Greek philosophers, medieval churchmen, and scholars. The historically existent dialogue of the past between religion, philosophy and "natural philosophy" was to these men a living and vital tradition. They did not eschew the union of physics and metaphysics. Certain of our men worked within the outlook of the parson-naturalists of England, which "held that the study of nature enables a fuller appreciation of His works and thus leads us to admire the Power, Wisdom and Goodness of God manifested in His Creation" (Merton, 1968:634). Lord Kelvin's work was to him "a kind of worship" (King, 1925:30); indeed, he began each of his physics classes with a prayer (King, 1925:29). James Clerk Maxwell saw the physical world, and man, as "Truth in form arrayed" (Campbell and Garnet, 1882:595) worthy of worship. "Worship?" he asked, "Yes, what worship better. . ." (Campbell and Garnet, 1882:617). The Physics of Stewart and Tait can only be described as pious. Tyndall was deeply committed to the philosophical ideas of the atomists, and felt that it was ". . . not a matter of indifference whether they . . .(were) . . . introduced with reverence or irreverence" (1874:318).

It is, of course, possible, and sometimes advantageous, to make empiric statements without reference to religion and philosophy, just as it is possible to make philosophical and religious statements without reference to empirics. Proceeding in this way, one is perhaps less likely to turn an enthusiasm into a dogma. However, building a wall between the different areas of inquiry also has drawbacks; one is more likely to give uncritical acceptance to propositions whose broader implications have not been given attention. On the whole, as Whitehead has suggested, physics and metaphysics benefit each other, while their separation "ruins" (1962b:56) philosophy and leads to a "natural science . . . (of) . . . no importance" (1962a:54). Further, as E. A. Burtt (1954:227) has commented, ". . . there is no escape from metaphysics. That is, from the final implications of any proposition or set of propositions."

The work of the men we shall consider must be viewed in the above light. Their work certainly involved enthusiasm, and ran the danger of dogmatic endorsement. But their wholistic discourses were also suited to bring these dangers to light, and further allowed play to the deeper intuitions. Modern science textbooks, being both pedagogic and parsimonious, do not (and perhaps cannot) bring the full interplay of these elements out. As a result, the student of physics is sometimes left unaware of many of the final implications of what he is taught. For example, thermodynamics texts teach the first and second laws as being part of the same analytical system; as being compatible with each other. Are they? In the historical record we find men who have challenged this position.

Again, in the textbook tradition, the current understanding of the natural "laws", or theoretic generalizations, the selected evidence supporting these generalizations, and brief reference to the discoverers all tend to produce a vision of the knowledge taught as being ultimately correct; in Kuhn's wording, "finished." The further impression that all this work has been cumulative is suggestive of the idea that the student's own contribution in science should be to build further on these current generalizations. But are these current generalizations really the product of cumulatively dovetailing thought, leading in the <u>one</u> correct direction for future research? Thomas Kuhn (1970:2) comments:

> The more carefully . . . (recent historians of science) . . . study, say, Aristotelian dynamics, phlogistic chemistry, or caloric thermodynamics, the more certain they feel that those once current views of nature were, as a whole, neither less scientific nor more the product of human idiosyncrasy than those current today. If these out-of-date beliefs are to be called myths, then myths can be produced by the same sorts of methods and held for the same sorts of reasons that now lead to scientific knowledge. If, on the other hand, they are to be called science, then science has included bodies of belief quite incompatible with the ones we hold today.

The typical thermodynamics text of today gives the impression that modern thermodynamics grew from certain foundations discovered, agreed upon, and laid down in the nineteenth century. While this is in a sense true, historical examination of nineteenth century thought indicates far less agreement than most textbooks imply on what we call the fundamental assumptions. Rather the different contributors to the development of thermodynamics held frequently differing views. Kelvin, for example, excepted life as an example of the operation of the second law (Thompson, 1910:1093). His view is far closer to the ideas of certain modern biologists (Oparin, 1968; Trincher, 1965; P.G. Kuznetsov, 1965; Auerbach, 1936) than to the current "orthodox" position in physics, which is that the second law applies equally and without exception to all processes, including life (Allis, Herlin, 1952; Bent, 1962; Angrist, Holper, 1967; and Young, 1964). Similarly, Ludwig Boltzmann's work is usually seen as quite supportative of the Clausius interpretation of the second law, which is that entropy can only increase (Feynman, 1963; Bent, 1965). Boltzmann's views are actually different; he proposed an entropy-symmetrical universe (Boltzmann, 1898; Brush, 1964). In distinction to the textbook tradition, historical study brings all of these differences out. In this sense it serves to reopen the discourse on fundamental concepts engaged in by the founders of thermodynamics, and in this way can be seen as complementary to the textbook type of presentation. But, it may be asked, is not methodology a sufficient guide to scientific conclusion? Why then History? Kuhn (1970:4), at least, comments as follows:

> First . . . is the insufficiency of methodological directives, by themselves, to dictate a unique substantive conclusion to many sorts of scientific questions. . . . Instructed to examine electrical or chemical phenomena, the man who is ignorant of these fields but who knows what it is to be scientific may legitimately reach any one of a number of incompatible conclusions. Among those legitimate possibilities, the particular conclusions he does arrive at are probably determined by his prior experience in other fields, by the accidents of his investigation, and by his own individual make-up. . . . Observation and experience can and must drastically restrict the range of admissible scientific belief. But they alone cannot determine a particular body of such belief. An apparently

> arbitrary element, compounded of personal and historical accident, is always a formative ingredient of the beliefs espoused by a given scientific community at a given time.

If this statement of Kuhn's is true, then possibly the 'orthodox' position in modern physics on the second law has an arbitrary element. It may be asked, is this 'orthodox' position the only, or only one of several equally legitimate possibilities? The historical records tend to shed light on such questions. For example, is the black hole hypothesis only something that could develop in terms of modern theory and methodology -- or could it have come much sooner? On this point John Wheeler (1973:80) comments:

> The idea of a black hole is very old. In 1798, French mathematician Pierre Simon Laplace noted that a star as dense as the sun, but extending out more than twice as far as the earth, could not give off light. A year later, Laplace published the details of the reasoning that led him to this conclusion.[7]

Could this idea have lain fallow, so to speak, for almost two hundred years, because philosophic and religious perspectives suggested other paths of research and thought? History, at any rate, suggests that we look at the past concord and conflict of thought in the open marketplace of ideas, particularly at the early stages of their development. On such stages, Thomas Kuhn (1970:4) comments: ". . . the early developmental stages of most sciences have been characterized by continual competition between a number of distinct views of nature, each partially derived from and all roughly compatible with, the dictates of scientific observation and method." It is on such a period in thermodynamics that we focus,

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[7]Wheeler (1973:80) continues: "To escape from the moon, Laplace explained, a projectile needs a speed of $1\frac{1}{2}$ miles per second. To escape from the Earth, it must start at 7 miles per second; or from the Sun at 383 miles per second. Laplace asked how big an object would have to be so that a projectile starting off with the maximum known velocity, the speed of light itself, would fall back defeated. This was the first mention of what investigators later began to call a black hole."

and we will find a number of very different views emergent.

Let us approach again our question as to whether elements of traditional Christian cosmology played a role in the development of the cosmological model of the second law. In regard to this question, it is relevant to ask also whether philosophical elements played a part in the development of the first law -- the conservation of energy. As stated earlier, physical evidence alone has been (and remains) incomplete with respect to the construction of a definitive model of the universe. A conceptual leap from partial evidence is required. Such a leap seems more or less needed for the attribution of any characterizing law to the universe as a whole. Apparently, such leaps were made by most of the early discoverers of the conservation principle.

Thomas Kuhn, in his article, "Energy Conservation as Simultaneous Discovery (Clagget, 1959:321-356), cites conceptual leaps from partial evidence on the part of Colding, Helmholtz, Liebig, Mayer, Mohr, and Seguin, and goes on to note that "Put bluntly, these pioneers seem to have held an idea capable of becoming conservation of energy for some time before they found evidence for it." Kuhn continues:

> Mohr jumped without warning from a defense of the dynamical theory of heat to the statement that there is only one force in nature and that it is quantitatively unalterable. Liebig made a similar leap from the duty of electric motors to the statement that the chemical equivalents of the elements determine the work retrievable from chemical processes by either electrical or thermal means. Colding tells us that he got the idea of conservation in 1839, while still a student, but withheld announcement until 1843 so that he might gather evidence. The biography of Helmholtz outlines a similar story. Seguin confidently applied his concept of the convertibility of heat and motion to steam engine calculations, even though his single attempt to confirm the idea had been totally fruitless.

Kuhn goes on to say that ". . . The persistent occurrence of mental jumps like these . . . suggests that many of the discoverers of energy conservation were deeply predisposed to see a single indestructible force at the root of all natural phenomena." Kuhn found the concepts of "Naturphilosophie" (Natural Philosophy) were both (a) conceptually congruent to and suggestive of conservation as a fundamental law of the universe, and (b) available to many of the men whose work he considered. Kuhn concludes that "Naturphilosophie could, therefore, have provided an appropriate philosophical background for the discovery of energy conservation" (Clagget, 1959:338).

Conceptual leaps from partial evidence are sometimes fruitful, sometimes not. It may be said that energy conservation has been fruitful as a hypothesis, but should not be received as a dogma. Nor has it been by certain researchers.[8] Let us look at a conceptual leap from partial evidence to the generalization of the second law to the universe as a whole. R. Clausius made such a leap on the basis of heat flows; Richard Feynman continues this procedure while considering the universal consequences of heat flows between hot rocks and cold water. Feynman (1963: 44-12) comments as follows:

> If we put together two objects that are at different temperatures, say T_1 and T_2, a certain amount of heat will flow from one to the other by itself. Suppose, for instance, we put a hot stone in cold water. Then when a certain heat Q is transferred from T_1 to T_2, how much does the entropy of the hot stone change? It decreases by Q/T_2. The heat will, of course, flow only from the higher temperature T_1 to the lower temperature T_2, so that Q is positive if T_1 is greater than T_2. So the change in entropy of the whole world is positive /emphasis added/, and it is the difference of the two fractions:

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[8] The Physical Science Study Committee (Physics, 1960:437) comments: "This assumption, that the total energy of the universe is constant, is the basis of most cosmological theories. But that is a daring generalization from our limited experience. We live in a small corner of the universe, and we have tested the validity of our physical laws over a very limited period of time. It is conceivable that these laws, including the law of the conservation of energy, are not rigorously correct . . . Here is one of the live scientific questions of today. Cosmologists are working hard to find out whether energy is completely conserved over the whole universe. And just now, for the first time, there is the possibility of actual experiments to decide between the rival theories."

$$S = \frac{Q}{T_2} - \frac{Q}{T_1}$$

Feynman has made a considerable jump from stones in water to the "whole world". Of course, his statement is pedagogic, and has been "elegantly" whittled down for simplicity. Still, the jump exists and is maintained throughout the text, and it is regarding this type of jump that Clifford (whose comments we shall examine later) criticized the cosmological application of the second law in the 1880's. A more careful position is taken by Kenneth W. Ford (1972:653), who comments:

> The logical terminus of the universe, assuming it to be a system obeying the same laws as the macroscopic systems accessible to experiment, is known as the "heat death," a universal soup of uniform density and uniform temperature, devoid of available energy, incapable of further change, a perfect and featureless final disorder. If this is where the universe is headed, we have had no hints of it as yet. Over a time span of ten billion years or more, the universe has been a vigorously active place, with new stars still being born as old ones are dying. It is quite possible that the long-range fate of the universe will be settled within science and need not remain forever a topic of pure speculation. At present, however, we have no evidence at all to confirm or contradict the applicability of thermodynamics to the universe as a whole.

As between Feynman's and Ford's generalization, Ford's is the more descriptively accurate. It also provides the foundation for the view that where the evidence is as yet indecisive, philosophical convictions may lead thought. Most frequently is this true when the model of the universe to be proposed holds profound implications in philosophy and religion. The traditional Christian, for example, adheres to a "Creation" model of the universe which is roughly compatible with revelation as given in the Bible. Adherents to other outlooks hold to very different models of the universe, and these beliefs are in many cases *not a matter of indifference* to the respective believers. A change in or challenge to such belief can produce a crisis for the believer, and the physicist is no less vulnerable in this regard than any other man. Suppose, for example, that a devout physicist is confronted by the newly forged principle of the conservation of energy. A devoted materialist then cites this law as tending to confirm the view that there has never been a "creation" of the world at all -- rather, nature has an unbroken material continuity. (We shall later see certain writers, either directly or by implication, take just such a stance.) This can produce a crisis for the believer; where is the "evidence" for Creation? Such confrontation was afoot in Kelvin's time, and had been augmented by the development and popular dissemination of Laplace's 'nebular hypothesis,' which assumed the material universe to be self-sufficient. On scientific crises, Kuhn (1970:88) has commented, "It is, I think, particularly in periods of acknowledged crisis that scientists have turned to philosophical analysis as a device for unlocking the riddles of their field."

Let us turn at this point to a more specific historical overview of the elements of our study. In the nineteenth century there was active debate over the Creation versus the material eternity of the world, and the second law came to be pivotally involved in the matter. But the debate existed far earlier, and the men whose thought we shall study were by their classical education probably more aware of it than we are today. Let us look at the early ideas, and trace their effects.

CHAPTER I

COSMOLOGY IN PHILOSOPHY AND RELIGION: AN OVERVIEW

This chapter focuses upon the definition of three religious and philosophical outlooks which appear significant in regard to nineteenth century thought on the cosmological application of the second law. All three outlooks are of ancient origin, and each has posited a distinctive and historically unchanging cosmological model of the universe. These cosmological models in turn appear to be consistent with several different nineteenth-century interpretations of the second law. Let us define these three outlooks and then turn to consider their historical positions in cosmology.

The first of these outlooks is scientific materialism, which has been defined in part by Whitehead (1962b:23) as ". . . the fixed scientific cosmology which presupposes the ultimate fact of an irreducible brute matter, or material, spread throughout space in a flux of configurations. In itself such a material is senseless, valueless, purposeless. It just does what it does do, following a fixed routine. . . ." Materialism holds that not only is the Deity absent from the world; he was never there. In this vein, Becker (cf. Brown and Perrin, ed., 1940:453) comments,

> Edit and interpret the conclusions of modern science as tenderly as we like, it is still quite impossible for us to regard man as the child of God for whom the earth was created as a temporary habitation. Rather must we regard him as little more than a chance deposit

> on the surface of the world, carelessly thrown up between two ice ages by the same forces that rust iron and ripen corn . . . The ultimate cause of this cosmic process of which man is a part . . . we know not. Whatever it may be, it appears in its effects as neither benevolent nor malevolent, as neither kind nor unkind, but merely as indifferent to us.

The remaining two outlooks are both religious, but differ in important ways from each other. Both conceive the material world to be in some sense the product of, and dependent upon, a higher, metaphysical reality which is not indifferent to life. As between the two religious outlooks, however, the perceived relationship between the material and the metaphysical worlds differs. In the traditional Christian view, as well as in early Iranian and Hebraic outlooks (Eliade, 1965:104,125) the original, unitary relationship between the physical and the metaphysical world at the time of creation has since been partly broken by sin. The now existing material world is hence to a degree imperfect, fallen, evil, while the metaphysical world remains perfect. In the other religious view, the relationship between the physical and the metaphysical worlds remains unbroken. The physical world remains essentially unfallen because it continuously partakes of, and reflects the goodness of, the metaphysical world. Examples of this latter outlook are to be found in optimistic strains of Hermetism and Neoplatonism (Yates, 1964:22; de Santillana, 1970:306) which influenced certain optimist variants of Christianity. In _The Varieties of Religious Experience_ (first given as the Gifford Lectures on Natural Religion delivered at Edinburgh in 1901-1902) William James characterized both the traditional, and the more optimistic variants of the religious outlook. James' characterizations may be apt for the focus of this paper, as they were drawn from nineteenth century observations and addressed at Edinburgh to that Scotch-Irish-English religious tradition which Kelvin, Maxwell and Tait in particular grew up within and partook of.

Describing two kinds of Christians, the "once-born" or "healthy-minded" and the "twice-born" (which in this paper is termed the 'traditional'), James gives the following characterizations: The healthy-minded is

> . . . the temperament which has a constitutional incapacity for prolonged suffering, and in which the tendency to see things optimistically is like a water of crystallization in which the individual's character is set. . . . This temperament may become the basis for a peculiar type of religion, a religion in which good, even the good of this world's life, is regarded as the essential thing for a rational being to attend to. This religion directs him to settle his scores with the more evil aspects of the universe by systematically declining to lay them to heart or make much of them, by ignoring them in his reflective calculations, or even, on occasion, by denying outright that they exist (1963:127).
>
> Now in contrast with such healthy-minded views . . . stands a radically opposite view, a way of maximizing evil, if you please so to call it, based on the persuasion that the evil aspects of our life are of its very essence, and that the world's meaning most comes home to us when we lay them most to heart . . . All natural goods perish. Riches take wings; fame is a breath; love is a cheat; youth and health and pleasure vanish. Can things whose end is always dust and disappointment be the real goods which our souls require? . . . We need a life not correlated with death, a health not liable to illness, a kind of good in fact that flies beyond the Goods of nature (1963:130-40).

It is to the ideal of this life beyond nature that the soul of the "twice-born" Christian turns.

We have, then, in summary three outlooks: the <u>materialistic</u>, which sees the world as material, morally neutral fact; the <u>traditional religious</u>, which sees this world as imperfect and in certain ways evil; and the <u>optimistic</u> <u>religious</u>, which sees this world as partaking of the goodness of the divinity. We have said as yet nothing of the particular cosmological model which each view has produced and adhered to in history, and we turn next to a brief historical outline of the cosmology propounded within each outlook. To consider certain views which had an influence on nineteenth-century thought we must go back to the Greek philosophers of pre-Christian antiquity. We will follow certain of their thoughts into the rise of Christianity, consider the Christian position, and conclude with three modern restatements of the three positions.

The Greek Outlook and Cosmology

The popular cosmology of Greek antiquity varied. At first there were almost as many particular beliefs as there were separate social groups. Out of these early beliefs Greek mythology arose. Kitto (1967: 195) notes

> The primitive Greek seems to have thought about the gods much as other primitive people do. Our life is in fact subject to external powers that we cannot control -- the weather, for example -- and these powers are 'theoi', gods. All we can do is try to keep on good terms with them. . . . To all the gods sacrifice must be offered in the prescribed form; any irregularity may be irritating to them. . . .

In general, creation is the prerogative of the god or gods. With respect to early cosmogony, Eliade (1965:18) notes that ". . . the act of the Creation realizes the passage from the non-manifest to the manifest or, to speak cosmologically, from chaos to cosmos. . . ." The gods enter a pre-existing chaos and either create or order the world, transforming it through their powers and their sacrifices into a 'cosmos' which in the original Greek means 'a well-ordered community'. The creation has a tendency to decay, and requires periodic regeneration by the deities, a regeneration in which man participates by sacrificial ceremony.

Primitive cosmogonic myths and practices were the heritage of the earliest Greeks. "But," as Kitto (1967:202) relates, "the future of Greek religious thought lay neither with mythology nor with the Olympian gods nor yet with the more personal 'mystery' religions. . . . It lay with the philosophers."

Democritus of Abdera (410 B.C.)

Democritus of Abdera is the first of the Greek philosophers whom we shall consider. (His views were to influence Maxwell and Tyndall, among others.) Recoiling from superstitious and sacrificial religion, and the popular view that both man and nature were subject to the arbitrary acts of the gods, he rejected all divinities and posed a material world whose operations were the embodiment of reason and law. De Santillana (1970:144) gives certain of the surviving fragments of his thought:

> Nothing comes about perchance, but all through reason and by necessity.
>
> Nothing can be created out of nothing, nor can it be destroyed and returned to nothing.
>
> There is no end to the universe, since it was not created by any outside power.
>
> By convention color, by convention sweet, by convention bitter; in reality nothing but atoms and the void.

The second fragment above is an early statement of the conservation principle. Matter is uncreated and imperishable. So too is the cosmos as a whole. Arrangements of atoms produce the visible world and its changes, and will continue to do so forever. The Roman poet T. Lucretius Carus (c. 99 B.C.) was to give an account of this doctrine (which was a forerunner of Laplace's 'nebular hypothesis'). We quote from the translation of W. E. Leonard (1957:204-208,4-6):

> Neither by counsel did the primal germs
> 'Stablish themselves, as by keen act of mind,
> Each in its proper place; nor did they make,
> Forsooth, a compact how each germ should move;
> . . . It comes to pass that these primordials,
> Diffused far and wide through mighty aeons,
> The while they unions try, and motions too,
> of every kind, meet at the last amain,
> And so become oft the commencements fit
> Of mighty things -- earth, sea, and sky, and race
> Of living creatures.

> Whence, Nature all creates, and multiplies
> And fosters all, and whither she resolves
> Each in the end when each is overthrown.
> This ultimate stock we have devised to name
> Procreant atoms, matter, seeds of things,
> Or primal bodies, as primal to the world.

As Brinton (1961:51) comments, this view is "austerely 'materialistic,' God or gods strikingly absent; but the (view) is somehow consolingly orderly in its final results, presenting a cosmology, inhuman indeed, but happily understandable by enlightened human beings." And de Santillana (1970:291) states, "Of all the doctrines of antiquity, Democritus' atomism is the only one which re-emerges practically intact in our era." It had a considerable effect on nineteenth-century thought.

The other two Greek philosophers we shall consider did not reject the realm of the metaphysical as Democritus did, but in the most typical of their thoughts, the metaphysical appears as a realm of pre-existant rational relationships.

<u>Aristotle of Stagira (384-322 B.C.)</u>

Between the thought of Democritus and that of Aristotle, de Santillana (1970:148) relates, there was a difference. Democritus had held, "Of that which ever is and has been (the material universe) there is no reason to inquire for the cause." But Aristotle does, in fact, deny assent:

> Democritus does not think fit to seek for a first principle to explain this "ever"; so while his theory is right insofar as it is applied . . . he is wrong in making it of universal application. Thus, a triangle has its angles always equal to two right angles, but there is nevertheless an ulterior cause of the eternity of this truth, whereas first principles are eternal and have no ulterior cause. . . . The metaphysician is showing his teeth. The issue is one of first and last things, and has not been settled to this day.

However, Aristotle along with Democritus viewed the universe as eternal in time. He perceived it as the "Unlimited", and also (after the biological model) to be in a sense alive, purposeful, teleological. His views are important to us in regard to the position which the Catholic church later took on them. Recognizing both his own views and those of a more materialistic outlook, Aristotle held

> Everything either is an origin or has an origin: the Unlimited has no origin, for that would be a limit of it. Moreover being an origin /or source or principle: Greek arche/ it is ungenerated and imperishable. . . . Therefore as I say, there is no origin for it, but it appears to be the origin of other things, and to encompass all things and direct all things, as those philosophers say who do not posit besides the Unlimited other causes such as Mind or Love; and this they say is the divine, for it is immortal and imperishable, as Anaximander and most of the writers on nature call it (cf. Phys. 203b6 DK 12 A 15).

With respect to time, matter and motion, Aristotle's views have been summarized by Vollert (1964:8) as follows:

> . . . time is inconceivable apart from the moment, which is the beginning of future time and the end of past time. Hence, there must always be time before and after any moment. And if time is limitless, motion, too, must be eternal, because time is the measure of motion and is itself a kind of motion. Moreover, motion necessarily implies the existence of things that are movable, indeed, of things that are moving. Therefore, things in actual motion have existed eternally (Timaeus, 27 D - 29B; 29 E - 30 C; 37 C - 38 B; Phys., VIII, 1, 251b 10-28; 251a 9-b 9).

". . . things in actual motion have existed eternally." In modern terms, Aristotle has described the universe as a "perpetuum mobile" of the second category. The Catholic church will later brand this view as a heresy, while accepting and re-interpreting Aristotle's teleology.

Plato of Athens (c. 320 B.C.)

The Platonic outlook is complex, and contains what de Santillana (1970:309) sees as two different paths of development: "Out of the Platonic complex, one way led to a thoroughgoing mathematization of the universe, open and speculative, such as the Pythagoreans had attempted;

the other, which was the choice of Plato's old age, concentrated upon an enclosed and rigid world order, dominated by an astral theology." With respect to the first direction of Plato's thought, Paul Friedlander (1964:27) comments:

> The cosmos of numbers, the harmony and proportion of musical strings and, on a larger canvas, the cosmos of the starry sky were replicas of perfect being; they pointed upward to a place beyond the heavens. It is, therefore, the sciences of this order, and above all their unity and integration in the Pythagorean system, that moved Plato.... Thus the world of forms, the realm of perfection, cannot be anything but a world of 'unchanging and harmonious order, where nothing can do or suffer wrong, where all is in order according to reason' (Republic 500c).

Immobile, unchanging, perfectly rational forms (might we, today, call them formulas?) stood within the metaphysical center and summit of reality. The physical world partook of and reflected them in its cyclical, and likewise eternal transformations. This idea came to exert a tremendous influence in the Greek philosophical outlook. Henri-Charles Puech (1957:40-41) comments:

> Dominated by an ideal of intelligibility which finds authentic and full being only in that which is in itself and remains identical with itself, in the eternal and immutable, the Greeks regarded movement and change as inferior degrees of reality, in which, at best, identity can be apprehended in the form of permanence and perpetuity, hence of recurrence. The circular movement which assures the survival of the same things by repeating them, by bringing about their continuous return, is the perfect and most immediate expression (hence that which is closest to the divine) of the absolute immobility at the summit of the hierarchy. . . . According to the famous Platonic definition, the time which is determined and measured by the revolution of the celestial spheres is the mobile image of immobile eternity which it imitates by moving in a circle. Consequently both the entire cosmic process and the time of our world of generation and decay develop in a circle or according to an indefinite succession of cycles, in the course of which the same reality is made, unmade, and remade, in conformity with an immutable law and determinate alternations. The same sum of being is preserved; nothing is created and nothing lost; moreover, certain thinkers of dying antiquity -- Pythagoreans, Stoics, Platonists -- went so far as to maintain that within each of these cycles of time, of these _aiones_, these _aeva_, the same situations recur that have already occurred in the preceding cycles and will occur in subsequent cycles--

> and so *ad infinitum*. No event is unique, nothing is enacted but once (for example the condemnation of Socrates); every event has been enacted, is enacted, and will be enacted perpetually; the same individuals have appeared, appear, and will appear at every turn of the circle. Cosmic time is repetition and *anakuklosis*, eternal return.

In the above view, we again see the conservation theme expressed: "The same sum of being is preserved; nothing is created and nothing lost." Plato's views, at their purest, may provide the basis for both a mathematical science of the world and a transcendent religion. And, as Kitto (1967:203) remarked, "Plato's conception of the absolute, eternal deity . . . prepared the world for the reception of a universal religion."

In fact, Plato's ideas influenced two very different religious outlooks. In his more optimistic ideas, the phenomenal or material world "participated in" and reflected the rationality of the forms. There was a dualistic but close union between the physical and the metaphysical. This view influenced the optimistic strains of Neoplatonism and Hermetism, which in turn influenced certain Christian thinkers and early scientists from the Renaissance onward. We will look briefly at one source of Neoplatonism which influenced Bruno, Fludd and among others, quite possibly Newton. It is the Corpus Hermeticum, a collection of gnostic sacred writings. On the writings contained in the Corpus Hermeticum, Francis A. Yates (1964:2) comments:

> The works which inspired the Renaissance Magus, and which he believed to be of profound antiquity, were really written in the second to the third centuries A.D. He was not returning to an Egyptian wisdom, not much later than the wisdom of the Hebrew patriarchs and prophets, and much earlier than Plato and the other philosophers of Greek antiquity, who had all -- so the Renaissance Magus firmly believed -- drunk from its sacred fountain. He is returning to the pagan background of early Christianity, to that religion of the world . . . which was the gnostic version of Greek philosophy. . . . Though cast in a pseudo-Egyptian framework, these works have been thought by many scholars to contain very few genuine Egyptian elements . . . they were certainly not written in remotest antiquity by an all-wise Egyptian priest (Hermes Trismegistus) . . . but by various unknown authors, all

probably Greeks, and they contain popular Greek philosophy of the period, a mixture of Platonism and Stoicism, combined with some Jewish and probably some Persian influences. They are very diverse, but they all breathe an atmosphere of intense piety.

There are two outlooks in them, one a "pessimist gnosis," the other an "optimist gnosis." Yates (1964:22) comments:

> For the pessimist (or dualist) gnostic, the material world heavily impregnated with the fatal influence of the stars is in itself evil; it must be escaped from by an ascetic way of life which avoids as much as possible all contact with matter, until the lightened soul rises . . . ascends, to its true home in the immaterial divine world.

This outlook conforms, in rough character, to the traditional Christian view of this world as fallen, degraded, with the true Christian being a pilgrim to the 'City of God.' The optimist gnosis takes a quite different view. Yates continues, "For the optimist gnostic, matter is impregnated with the divine, the earth lives, moves with a divine life, the stars are living, divine animals, the sun burns with a divine power, there is no part of Nature which is not good for all are parts of God." The following excerpts from the Corpus Hermeticum (cf. Yates: 1964:31-34) render the elements of the optimist gnosis which are of interest in this study:

> Eternity is the Power of God, and the work of Eternity is the world, which has no beginning, but is constantly becoming by the action of Eternity. Therefore nothing that is in the world will ever perish or be destroyed, for Eternity is imperishable.
>
> And all this great body of the world is a soul, full of intellect and of God, who fills it within and without and vivifies the All.
>
> Is God then in matter, O Father?
>
> Where could matter be placed if it existed apart from God? Would it not be a confused mass, unless it were put to work? And if it is put to work by whom is that done? The energies which operate in it are parts of God. Whether you speak of matter, or bodies or substance, know that these things are energies of God who is the All. In the All there is nothing which is not God. Adore this word, my child, and render it a cult.

Yates (1964:447ff) has suggested that the Platonic elements of this optimist gnosis helped to emotionally fire the scientific imagination of the sixteenth and seventeenth centuries. E. A. Burtt notes the influence of Neo-Platonism on Bruno, Kepler, Copernicus, Nicholas of Cusa, and others. In that view, "The world is an infinite harmony, in which all things have their mathematical proportions" (Burtt, 1954:52ff). Of Newton, Giorgio de Santillana (1968:28) writes: ". . . it was the Hermetic mysteries that he was after . . . The subject of the Hermetic Philosophy (so named after the mythical master, Hermes the Thrice-Greatest) was the cosmos itself and its interlocking forces . . . now lost to modern consciousness but deeply studied by Newton in a multitude of texts that no one can even read now, or cares to." Considering Neo-platonism as a form of "scientific religion," de Santillana (1970:313) relates: ". . . the ideas of the Platonic lineage find their way back into astronomy, and physics, and live on in our universe of periodicities, electromagnetism, and relativistic space-time."

The other views of Plato -- the views of his old age -- as de Santillana commented, led in a different direction. It was a more pessimistic one. The political strife in Greece which he lived through brought him finally to the view that this world was far from the "good." He felt himself to be in the last and worst -- the 'iron' age of a cosmic cycle. His despair was exemplified in the Republic (cf. Cornford, 1967:320) where he has Socrates, who had been speaking of the just state, say dispiritedly to Glaucon, ". . . perhaps there is a pattern set up in the heavens for one who desires to see it and, seeing it, found one in himself. But whether it exists anywhere or ever will exist is no matter; for this is the only commonwealth in whose politics he can ever take part."

Cornford has added, ". . . this passage inspired both Stoics and Christians with the idea of the City of God."

Plato's speculative account of "creation" in the Timaeus, which was more an amalgam of the popular myths of his day than his own deepest thought, also came to inspire later theological imaginations. In that tale a demiurge, acting in the name of God, descended to a chaotic world and ordered it. This view was maintained and elaborated upon in certain pessimist gnostic cults. De Santillana (1970:311) comments:

> It is a strange but not unnatural outcome of Plato's astral theology . . . His fantasy of a demiurge or divine craftsman compounding and shaping the universe in imitation of the world of Ideas is now seized upon with eager pessimism. Maybe the world <u>is</u> the work of a fallen intelligence, separated from the upper realm of light. . . . The initial duality between spirit and matter set by Plato is pushed here to its extreme limits, the whole of the material world having become pure darkness and evil, the consequences of cosmic sinfulness.

The more theological side of Plato's thought came to be influential in shaping the traditional Christian outlook. With certain changes, it roughly transforms into traditional Christian dualism, tinged with pessimism for this world. Eschatologically, however, the Platonic concepts never themselves made the radical break, both qualitative and temporal, between the Deity and the world that Christian theology later posited. Let us turn now to the rise of the Christian outlook.

Christian Beliefs

It was against what it perceived as a pagan outlook that early Christian belief developed, and there was confrontation. As Claude Tresmontant (1957:132) has commented:

> By declaring, in the very heart of Athens, that God created the cosmos, St. Paul made a frontal attack on the fundamental principle of all the philosophy of antiquity. According to that philosophy, the cosmos <u>is</u> God, uncreated, existing from eternity; it has no need of a creator, it is all-sufficient, necessary, it is consistency itself. At most, it requires a <u>demiurge</u> to put it in order, for order is

> preceded by chaos . . . [time] was said to by cyclic, recurring: time chases its own tail. This is the 'endless returning' of the metaphysics, cosmogonies and mythologies of pagan antiquity.

Between the philosophy of antiquity and the Christian outlook, there was utter confrontation. Christian belief was not secured on the basis of argument; it demanded nothing less than conversion, conversion based on revelation. Vollert (1964:x) comments: "On the basis of revelation, as conveyed in the scriptures and an undeviating tradition, the Church has repeatedly taught, in the face of error, that God alone lacks a beginning and is eternal, and that He created the universe in a condition of successive duration following on a first moment." And Lynn White, Jr. (1968:37) states:

> Naturally to the early Christians, the pagan belief in purposeless temporal undulation was entirely unacceptable, and the idea of cosmic repetitive cycles was the worst of blasphemies. From such a theory it follows, writes Origen, that "Adam and Eve will do once more exactly what they have already done; the same deluge will be repeated; the same Moses will bring the same six-hundred thousand people out of Egypt; Judas will again betray his Lord; and Paul a second time will hold the coats of those who stone Stephen." Obviously no such notion could be held by a Christian. "God forbid," cries St. Augustine, "that we should believe this. For Christ died once for our sins, and, rising again, dies no more." The axiom of the uniqueness of the Incarnation required a belief that history is a straight-line sequence guided by God. And as the Church became the exclusive cult of the Roman Empire, the doctrines of undulation and recurrent cycles vanished from the Mediterranean world. No more radical revolution has ever taken place in the world outlook of a large area.

Pitrim Sorokin (1937:368-369), writing on the development of Christianity in Volume II of his Social and Cultural Dynamics, gives the following portrait:

> So far as the complete history of the world and of mankind is concerned, the Christian conception of it assumed a specific form. First, the empirical world and its duration in time, as well as time itself, was regarded as finite, having a beginning (Tertullian's natum et factum) and destined to have an end. Second, the initial point of this history and the final terminal point were both viewed as perfect: the Eden of Adam and Eve at the beginning and the City of God at the end, after the Last Judgment. The intermediate link,

> that is, practically the whole of human history, that lasts between the Fall and the Last Judgment, was viewed as something infinitely more degraded than the initial and the final terminal points.
>
> This whole history of "the City of Man" is purely temporary. True Christians in this world are but pilgrims. Their permanent place is "the City of God."

The reaction of the Catholic church to the re-introduction of Aristotle's works in thirteenth-century Europe provided further opportunity for affirmation of its dogma. In 1215, the Fourth Council of the Lateran defined that

> God alone has no beginning but always is and always will be; the eternal God is the one and only principle of all things, 'Creator of all things visible and invisible, spiritual and corporeal; by His almighty power, at the beginning of time He created both orders of creation alike out of nothing, the spiritual and the corporeal world, the angelic and the material (cf. Vollert, 1964:3).

Against this statement came Aristotle's thought. Vollert (1964:xi) relates it:

> Now the theologian-philosophers of Paris were being confronted with something 'new,' the moving cause, the eternal motion and eternally moved world of Aristotle's physics. . . . The suspicion of and hostile reaction to this new naturalistic Greek world-view [led] to the condemnations of 1210, 1215, and 1270. . . . St. Bonaventure led what Gilson has aptly termed the "theological reaction" that eventually culminated in the condemnation of 1277.

While Aristotle's teleological views were acceptable, even welcomed by the Church, the churchmen clearly separated God and his prerogatives from the material world, which remained inferior to the Deity.

Specifically, how does the above view, which has been maintained by the church to the present time, affect the research stance of the scientist who is a devout Christian? Vollert and others (1964:4-5) state:

> The Vatican Council, in its teaching about God the Creator, opposed pantheism, which fosters two heresies about creation: the eternity of the world, and the necessity of . . . emanation. To overthrow the basic error of pantheism in all its manifestations, the Council proclaims that creation was effected in time, and stresses God's complete freedom in creating. . . . Consequently the doctrine that the universe has a temporal duration is defined as a dogma of faith. . . .

> This dogma of faith is no obstacle to scientific exploration. Revelation teaches that the world began, but does not date that beginning; science has unimpeded liberty to search for the initial state from which the universe took its origin. /Emphasis added/

The thoughts of Whewell, Kelvin, Stewart, Tait and others, whose work we shall come to examine, appear to be harmonious with the above mandate. More recently, in the 1940's the one-shot "big-bang" theory of the origin of the present universe proposed by the Catholic theologian-astronomer Lemaitre, is consistent with the Church's position. On this model Nigel Calder (1971:136) comments:

> The evidence grows that everything after the creation of our galaxy -- including the origin of the Earth and of life -- are explicable as a chancy but not mysterious series of physical and chemical processes. Any opportunity for supernatural explanations of the material world is, therefore, driven right back to the creation of the matter of the universe. . . . Is there a constructional job for God, so far away, so long ago? Monseigneur Lemaitre certainly thought so. . . . In propounding his theory of the Primaeval Atom, the Belgian astro-priest explicitly sought to modernize the opening verses of the Bible without contradicting them.

In his address of 1951 to the Vatican Academy of Science, Pope Pius XII made the following remarks on the Lemaitre model of the universe:

> If we look back into the past at the time required for this process of the "Expanding Universe", it follows that, from one to ten thousand million years ago, the matter of the spiral nebulae /galaxies/ were compressed into a relatively restricted space at the time the cosmic processes had their beginning. . . .
>
> If the scientist turns his attention from the present state of the universe to the future, even the very remote future, he finds himself constrained to recognize, both in the macrocosm and in the microcosm, that the world is growing old. In the course of billions of years, even the apparently inexhaustible quantities of atomic nuclei lose utilizable energy and, so to speak, matter becomes like an extinct and scoriform volcano. And the thought comes spontaneously that if this present cosmos, today so pulsating with rhythm and life is, as we have seen, insufficient to explain itself, with still less reason, will any such explanation be forthcoming from the cosmos over which, in its own way, the shadow of death will have passed. . . . (cf. Shapley, 1958:92-93).

The church has in actuality had what may be called a quasi-empiric precursor of the second law, and its application to the universe, since 258 A.D. An almost poetic rendition of it has been given by

Saint Cyprian:

> The world itself now bears witness to its approaching end by the evidence of its failing powers. There is not so much rain in winter for fertilizing the seeds, nor in summer is there so much warmth for ripening them. The springtime is no longer so mild, not the autumn so rich in fruit. Less marble is quarried from the exhausted mountains, and the dwindling supplies of gold and silver show that the mines are worked out and the impoverished veins of metal diminish from day to day. The peasant is failing and disappearing from the fields, the sailor at sea, the soldier in the camp, uprightness in the forum, justice in the court, concord in friendships, skill in the arts, discipline in morals. Can anything that is old preserve the same powers that it had in the prime and vigour of its youth? It is inevitable that whatever is tending downwards to decay and approaches its end must decrease in strength, like the setting sun and the waning moon, and the dying tree and the failing stream. This is the sentence passed on the world; this is God's law: that all that has risen should fall and that all that has grown should wax old, and that strong things should become weak and great things should become small, and that when they have been weakened and diminished they should come to an end.
>
> --ST. CYPRIAN, *Ad Demetrianum*, c. iii.

God and the Universe

Out of the viewpoints examined in this chapter three models of the universe emerge. Each model attributes certain characteristics to the universe and to God. We will describe the models and then look at explicit statements of them. In the traditional Christian view, both the posited mutability and temporal decay or "unwinding" of the universe point to its dependence upon and origin at the hands of a "creator" God. In the optimistic religious view, the posited beauty, form and flawless functioning of the universe imply its continuing existence grounded in the Divine. However, on this latter view there is no suggested physical decay or unwinding pointing back toward a past creation. In this view (as St. Thomas Aquinas has held), "Without the aid of revelation it [is] impossible to know that the world had a beginning in time. . ." (Mascall, 1957:146). Finally, there is the materialist position which posits a universe of non-degradable physical processes. The non-degrading nature of these processes is in turn seen as implying a self-sufficient universe. "Creation" and "Creator" alike are seen as superfluous assumptions.

The materialistic and the optimistic religious outlooks essentially agree in positing a non-degrading universe. As a result, debate between these outlooks is on this point without substantive empiric difference. Between these two views and the outlook of traditional Christianity, however, there is substantive difference, and physical evidence becomes relevant to debate. The physical evidence in turn involves the second law, and the outlooks we have seen are not indifferent to its interpretation. The traditional Christian view endorses the universal application of the second law as evidence for creation. The religious optimist tends to remain open on or mildly critical toward the universal application of the second law. The materialist rejects its application as a universal law.

Let us look at several relatively modern statements in which these points are crystallized.

<u>The Traditional Christian View</u>

As noted in the introduction, the second law provided a thermodynamic foundation for the theory of the "one-shot" big bang and expanding universe. In his address to the Vatican Academy of Sciences (November, 1951) Pope Pius XII commented as follows on this model of the universe:

> With the same clear and critical look with which it examines and passes judgment on facts (the scientific mind) perceives and recognizes the work of creative omnipotence, whose power, set in motion by the mighty <u>fiat</u> pronounced milliards of years ago by the Creating

> Spirit, spread out over the universe, calling into existence with a gesture of generous love, matter bursting with energy. In fact, it would seem that present day science, with one sweeping step back across millions of centuries, has succeeded in bearing witness to that primordial Fiat Lux uttered at the moment when, along with matter, there burst forth from nothing a sea of light and radiation, while the particles of chemical elements split and formed into millions of galaxies . . . Thus, with the concreteness which is characteristic of physical proofs, it has confirmed the contingency of the universe and also the well-founded deduction as to the epoch when the cosmos came forth from the hands of the creator.
>
> Hence, creation took place in time. Therefore, there is a Creator. Therefore, God exists. Although it is neither explicit nor complete, this is the reply we were awaiting from science, and which the present human generation is awaiting from it. . . (cf. Mascall, 1957:151-2).

Robert E. D. Clark (1961:18ff), speaking as a traditionally oriented Protestant theologian, affirms the same view while attributing the "entropy" argument to Newton. Calling all other positions on the second law "idle speculation," he states, "Taken as a whole, science gives the strongest support to the view that entropy does increase: in addition, if we do not assume this to be so, all science, all rational thought even, becomes impossible. . . ."

The Optimist Religious View

On the other hand, E. L. Mascall, speaking as a Protestant who endorses the Thomist position, says, "The first point that needs to be emphasized is that for Christian theology the notion of creation is not primarily concerned with a hypothetical act by which God brought the world into existence at some moment in the past, but with the incessant act by which he preserves the world in existence so long as he wills that it shall exist" (1957:133). Mascall goes on to explore several lines of thought which challenge the classical interpretation of the second law, among them Tolman's relativistic thermodynamics. He states:

> The argument /for creation/ is based entirely on the classical or non-relativistic thermodynamics. Now, relativistic thermodynamics, which is the true theory, is considerably different from classical thermodynamics. Thus, in classical thermodynamics, a system which is in thermal equilibrium must be at a uniform temperature throughout; but in relativistic thermodynamics, a temperature gradient is necessary to prevent the flow of heat from regions of higher to regions of lower gravitational potential which are in thermal equilibrium. This simple example shows the need for caution, and the importance of using, in any general argument regarding the universe, not the classical laws, but the modified form of them which has been discovered by Professor Tolman . . . He has shown that in certain cases a universe expanding or contracting at a finite rate can do so reversible, without tending to the ultimate "heat death" which would be predicted by classical thermodynamics (1957:141).

Thus he concludes, "The Christian may well rejoice in the fact that the heavens declare the glory of God and the firmament sheweth his handiwork, while adopting an attitude of extreme detachment towards arguments that attempt to prove the existence of God from the Second Law of Thermodynamics or the recession of the extra-galactic nebulae" (1957:166).

Finally, let us look at certain statements of Ernst Haeckel for the materialist position.

The Materialist Position

Ernst Haeckel (1900:235-247), reacting against religious views on creation and the second law, comments:

> According to this creationist theory, then, God has "made the world out of nothing." It is supposed that God (a rational, but immaterial, being) existed by himself for an eternity before he resolved to create the world. Some supporters of the theory restrict God's creative function to one single act; they believe that this extramundane God (the rest of whose life is shrouded in mystery) created the substance of the world in a single moment, endowed it with the faculty of the most extensive evolution, and troubled no further about it. This view may be found, for instance, in the English Deists in many forms. It approaches very close to our monistic theory of evolution, only abandoning it in the one instant in which God accomplished the creation. Other creationists contend that God did not confine himself to the mere creation of matter, but that he continues to be operative as the "sustainer and ruler of the world." Different modifications of this belief are found, some approaching very close to pantheism and others to complete theism. All these and similar forms of belief in creation are incompatible with the

> law of the persistence of matter and force; that law knows nothing of a beginning.
>
> In the theory of Clausius . . . All difference of temperature must ultimately disappear, and the heat must be equally distributed through one inert mass of motionless matter. All organic life and movement must cease when this maximum of entropy has been reached. That would be a real "end of the world."
>
> If this theory of entropy were true, we should have a "beginning" corresponding to this assumed "end" of the world -- a minimum of entropy, in which the differences in temperature of the various parts of the cosmos would be at a maximum. Both ideas are quite untenable in the light of our monistic and consistent theory of the eternal cosmogenetic process; both contradict the law of substance. There is neither beginning nor end of the world. The universe is . . . eternally in motion; the conversion of kinetic into potential energy, and *vicissim*, goes on uninterruptedly; and the sum of this actual and potential energy remains constant. The second thesis of the mechanical theory of heat contradicts the first, and so must be rejected.

Haeckel's comments round out the three positions we have been examining. Let us sum them up.

Summary

The three philosophical and religious positions which we have considered are the traditional Christian, the optimistic[1] religious, and the materialistic. Their positions with regard to what may be called second law cosmology are respectively, pro, open ranging to negative, and negative. As we proceed, we will find that these positions are adhered to with considerable consistency by other writers, including those who participated in the development of the second law in the nineteenth century.

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[1]The term "optimist" is employed in William James' and Francis Yates' usage. It is meant to cover certain variants of Platonism and Hermetism, Deism, Transcendalism, pantheism and theism.

CHAPTER II

RELATIONSHIP BETWEEN THE FIRST AND SECOND LAWS OF THERMODYNAMICS

In the last chapter we looked at religious and philosophical positions on the nature of the universe and the second law. The models of the universe posited by these outlooks are contradictory at many points, and are intended to be so, as they offer substantive differences of belief. The universe cannot be both created and uncreated, sustained and not sustained, self-sufficient and not self-sufficient, degrading and non-degrading, temporal and eternal. Among the contradictions posited between the different outlooks, Ernst Haeckel suggests that the first and the second laws of thermodynamics are contradictory. Are they?

Suppose that we view the religious and philosophical arguments, with all their contradictions, as peripheral appendages to physics itself, and banish them. Will they and all their contradictions disappear, leaving a body of physical cosmology in which all remaining elements are congruent and compatible -- or do the contradictions indeed carry right down into the physical considerations? In this respect we shall look at the cosmological models of Sir James Jeans and Sir Arthur Eddington, both developed in the early part of the twentieth century and still dominant today as the general theory of the expanding universe.

The Cosmology of Sir James Jeans

Let us examine the cosmology of Sir James Jeans with respect to the predictions of the first and the second laws of thermodynamics for the past and future states of the observable universe. Jeans' statements are taken from the last chapter of his book, The Universe Around Us, which was written in 1929. By that time the first and second laws of thermodynamics had been widely accepted as compatible, and together with subsidiary axioms they comprised the theoretic foundations of classical thermodynamics. The universe was seen as having a constant overall sum of energy, and to be in motion or engaged in transformations the net direction of which was given by the second law. The two concepts appear compatible when applied over short time periods in the present. But what happens to their apparent compatibility when we consider the distant future and distant past of the observable universe? The following selected quotations give the major points of Jeans' cosmology:

> The solid substance of the material universe is continually dissolving away into intangible radiation. . . The same transformation of material weight into radiation is in progress in all the stars....
>
> It is natural to ask whether a study of the universe as a whole reveals these processes as part only of a closed cycle, so that the wastage which we see in progress in the sun and stars . . . is made good elsewhere. . . . Is the physical universe a . . . cyclic system, or ought it rather to be compared to a stream which, having no source of replenishment, must cease flowing after it has spent itself? . . .
>
> The second law of thermodynamics rules out any such [cyclic] possibility. . . . Energy is indestructible as regards its amount, but it continually changes in form, and generally speaking there are upward and downward directions of change. It is the usual story -- the downward journey is easy, while the upward is either hard or impossible. [For example] . . . radiative energy tends always to change into a form of longer wave length, never into a form of shorter wave length. . . .
>
> Energy cannot run downhill forever, . . . And so the universe cannot go on forever; sooner or later the time must come when its last erg of energy has reached the lowest rung on the ladder of descending availability, and at this moment the active life of the universe must cease . . . . We are left with a dead, although possibly a warm, universe -- a "heat-death."

> Such is the teaching of modern thermodynamics. . . . With universes as with mortals, the only possible life is progress to the grave.
>
> . . . Perhaps it is as well: it is hard to see what could accrue from an eternal reiteration of the same theme, or even from endless variations of it.
>
> The final state of the universe will, then, be attained when every atom which is capable of annihilation has been annihilated, and its energy transformed into heat-energy wandering forever round space. . . .
>
> Conversely, as we go backwards in time, the total material weight of the universe must continually increase. . . . It is clear that we cannot go backward in time . . . so far that this total weight becomes infinite. . . .
>
> . . . And, wherever we fix it, our next step back in time leads us to contemplate a definite event, or series of events, or continuous process, of creation of matter at some time not infinitely remote. In some way matter which had not previously existed, came, or was brought, into being.
>
> . . . If we want a concrete picture of such a creation, we may think of the finger of God agitating the ether.
>
> We may avoid this sort of crude imagery by insisting on space, time and matter being treated together and inseparably as a single system, so that it becomes meaningless to speak of space and time as existing at all before matter existed. Such a view is consonant not only with ancient metaphysical theories, but also with the modern theory of relativity. . . . This brings us very near to those philosophical systems which regard the universe as a thought in the mind of its creator, thereby reducing all discussion of material creation to futility.
>
> . . . it is impossible for the human mind to comprehend the full plan of the universe, . . . (it is for this reason that the plain man) decides that his own efforts shall stop this side of the creation of matter. This last point of view is perhaps the most justifiable of all from the purely philosophic standpoint. . . . There is no need even to worry overmuch about apparent contradictions. . . . a contradiction worries us about as much as an unexplained fact, but hardly more: it may or may not disappear in the progress of science (Jeans, 1929:305-325).
>
> (Emphasis supplied)

There are a number of statements above. The ones of most direct interest have been underlined. First let us note that as he takes us backward in time, Jeans posits a "hidden singularity" which contravenes the first law of thermodynamics -- creation, perhaps over a period of time, of matter (and hence, energy). Next, he suggests that the "point of view" of the "plain" man has the best philosophical justification for stopping his efforts to understand the universe "this side of the creation of matter." He goes on with a statement that "There is no need even to worry overmuch about apparent contradictions." What "apparent contradictions" does Jeans refer to?

The law of the conservation of energy states that the substance of the universe, energy, can be neither created nor destroyed, and its sum total is a constant in all transformations. If energy can be neither created nor destroyed, and if the universe now has "X" amount of energy, it must have existed with "X" amount of energy yesterday, and it will so exist tomorrow. Pursuing this line of thought, we see that constancy of energy implies that the universe has always existed. It cannot, on this view, have been created, for creation abridges conservation.

The second law of thermodynamics states that the energy of the universe is at present undergoing a net directional transformation from a past state characterized by maximum availability to a future state characterized by maximum unavailability. The process is called "increase of entropy" and an increase of entropy signifies a decrease in the relative availability of energy.

The present observable state of the universe, considered with the second law, entails the conclusion that at a period not infinitely remote, the universe must have been in a state of absolutely minimum entropy, or maximum availability of energy. By all the criteria of thermodynamics, such a state is unstable, and tends spontaneously to move to states of greater entropy and lower availability of energy. The universe cannot, therefore, have sat motionless through all prior eternity in this state of minimal entropy, and then for no reason "blossomed" into its present state.

So, we are moved to ask, what caused the universe to assume this state of minimal entropy? No entropy-decreasing natural process which may have occurred before this state came to exist can be invoked as an explanation, as classical thermodynamics axiomatically holds that it is impossible for natural energy transformations to occur in such a way that entropy, in the net, decreases as one goes forward in time; nor can entropy continue to decrease forever as one goes backward in time. In denying the efficacy of natural causation on net entropy decreases, classical thermodynamics is driven to assume, if it attempts an explanation at all, that an extra-natural force or agent either (1) created the universe at this time (Jeans' explanation) or (2) intervened to produce the state of minimum entropy. Sir Arthur Eddington, in The Nature of the Physical World, notes this dilemma:

> There is no doubt that the scheme of physics as it has stood for the last three-quarters of a century postulates a date at which either the entities of the universe were created in a state of high organization (low entropy), or pre-existing entities were endowed with that organization which they have been squandering ever since....
>
> Scientists and theologians alike must regard as somewhat crude and naive theological doctrine which (suitably disguised) is at present to be found in every textbook of thermodynamics; namely, that some billions of years ago God wound up the material universe and has left it to . . . (run down) . . . ever since. This should be regarded as the working-hypothesis of thermodynamics rather than its declaration of faith. It is one of those conclusions from which we can see no logical escape -- only it suffers from the drawback that it is incredible (1963:84).

The conclusion may or may not be incredible, but there is clearly a problem. If classical thermodynamics does not invoke God as a creator or orderer of the world, then it must pose the low-entropy event as a "singularity", an event not covered by natural laws.

The "Past Creation" postulate of classical thermodynamics, furthermore, shifts this problem as far away from empirical attention as possible by positing the singularity far backward in time, away from direct observation. Fred Hoyle, in The Nature of the Universe, raises exactly this point about the problem. He says,

> On scientific grounds this big bang assumption . . . is an irrational process that cannot be described in scientific terms . . . On philosophical grounds too I cannot see any good reason for preferring the . . . idea. Indeed it seems to me in the philosophical sense to be a distinctly unsatisfactory notion, since it puts the basic assumption out of sight where it can never be challenged by a direct appeal to observation (1950:113).

Hoyle attempts a bold solution: he denies the present operation of the first law and proposes continuous creation. He states:

> Where does the created material come from? It does not come from anywhere. Material simply appears -- it is created. At one time the various atoms composing the material do not exist, and at a later time they do . . . . Some people have argued that continuous creation introduces a new assumption into science -- and a very startling assumption at that. Now I do not agree that continuous creation is an additional assumption. It is certainly a new hypothesis, but it only replaces a hypothesis that lies concealed in the older theories, which assume . . . that the whole matter in the universe was created . . . at a particular time in the remote past (1950:112).

Hoyle proposes a universe which appears to our view to have a constant amount of matter and energy within the limits of our observation, because it is in continuous and eternal expansion, while the velocity of light plus the red shift limits the distance over which we can see. Hoyle sums his model up as follows:

> To conclude, I should like to stress that so far as the Universe as a whole is concerned the essential difference made by the idea of continuous creation of matter is this: Without continuous creation the Universe must evolve toward a dead state. . . . The details of the way this happens are different in the different theories that have been put forward, but the outcome is always the same. With continuous creation, on the other hand, the Universe has an infinite future in which all its present very large-scale features will be preserved (1950:119).

In Hoyle's system, we can maintain the second law, but only at the cost of denying the first law. Hoyle's matter comes from nowhere, and his universe expands forever. We have replaced one difficulty with two others.

The proliferation of difficulties which lie in this area of cosmology are somewhat reminiscent of those which infested the Ptolmaic system in astronomy long ago. It can be said that the conservation law and an entropy-symmetrical second law, as applied to the universe, would be fully compatible. Similarly, the classical statement of the second law and a non-conservation law would be fully compatible with each other, providing one can put up with the idea that something can come from nothing. Or, has God done it?

For the present, let us return to Jeans' cosmology. Jeans has resolved the contradictions which he has noted by saying, in effect, that God did do it. What, in turn, does the universe as Jeans portrays it imply about God? For one thing, he is not imminent in the universe in a sustaining way. Rather, since the time of creation, he has not intervened; his creation is running down, like a clock wound only once. In Jeans' view, God's universe is dying. What magnificent pessimism -- the universal process is an "annihilation!" What place does life have in such a creation? Jeans suggests that life is perhaps ". . . Something of the nature of a disease, which affects matter in its old age when it has lost the high temperature and capacity for generating high-frequency radiation with which younger and more vigorous matter would at once destroy life" (1929:324). Or, he asks, "Is it the climax toward which the whole creation moves?" If it is, it is equally certain that life shall have no future home in Jeans' universe, for "With universes as with mortals, the only possible life is progress to the grave" (1929:309). To sum up Jeans' model of the universe: it is equivalent to, if more sophisticated than, the model advanced by St. Demetrian which we presented in Chapter I. For both men a sentence has been passed on the world -- that all things should grow weak and wax old, and come to an end.

The Cosmology of Sir Arthur Eddington

In its physical particulars, the universe as seen in Eddington's cosmology conforms to the model given by Jeans. Eddington's cosmological reflections are found in New Pathways in Science (1959) and The Nature of the Physical World (1963), both reprints of lectures delivered in 1927 and 1934, respectively.

We need not repeat the physical considerations. Let us instead concentrate on Eddington's philosophical reflections as furnished in these two works. While Eddington notes that the assumptions of classical thermodynamics, as applied in cosmology, are "Incredible" (1958:85), he goes on to say that "I can make no suggestion to evade the deadlock." He does consider the predictions from kinetic theory that the universe may pull off a chance statistical fluctuation and get going again sometime in the future, but rejects the idea as "absurd" (1958:74), and goes on to say, "The law that entropy increases -- the second law of thermodynamics -- holds, I think, the supreme position among the laws of Nature." Why does he feel this way about the second law? Eddington's philosophical outlook may hold one key here. While noting that ". . . a single winding-up (of the universe) at some remote epoch is not really the kind of relation between God and his world that brings satisfaction to the mind," he goes on to say, "I see no escape from our dilemma. One cannot say definitely that future developments of science will not provide an escape; but . . .

> I find no difficulty in accepting the consequences of the present scientific theory as regards the future -- the heat-death of the universe. It may be billions of years hence, but slowly and

> inexorably the sands are running out. I feel no instinctive shrinking from this conclusion. From a moral standpoint the conception of a cyclic universe, continually running down and continually rejuvenating itself, seems to me wholly retrograde. Must Sisyphus for ever roll his stone up the hill only for it to roll down again every time it approaches the top? That was a description of Hell. If we have any conception of progress as a whole reaching deeper than the physical symbols of the external world, the way must, it would seem, lie in escape from the Wheel of things. It is curious that the doctrine of the running-down of the physical universe is so often looked upon as pessimistic and contrary to the aspirations of religion. Since when has the teaching that "heaven and earth shall pass away" become ecclesiastically unorthodox (1959:59)?

> Whoever wishes for a universe which can continue indefinitely in activity must lead a crusade against the second law of thermodynamics; the possibility of re-formation of matter from radiation is not crucial and we can await conclusions with some indifference (1963:86).

Surely there is an emotional attitude here, linked in turn to a philosophical and religious outlook, which is associated with Eddington's scientific cosmology; endorsement of the second law as "supreme", with a feeling of "some indifference" expressed toward other alternatives. In one respect particularly, the views of Eddington and Jeans are congruent, for speaking of the heat death, Jeans had said, "Perhaps it is as well; it is hard to see what advantage could accrue from an eternal reiteration of the same theme, or even endless variations of it" (1929:311). Both men have expressed clear distaste for a cosmos of cyclical, eternal fluctuation.

We are back to the religious and philosophical positions, and have not succeeded in eliminating the apparent contradiction between the first and the second laws of thermodynamics. Can these two laws be seen as simply the airtight, finished and flawless findings of a philosophy-free physical science? History, at least, suggests a different picture. It suggests that both of these "laws" are still unfinished hypotheses about the fundamental nature of the universe, first developed from a union of physical, philosophical and religious thought. These hypotheses, entailing physical consequences which can be investigated empirically, embody the fundamental cosmological postulates of differing philosophical and religious outlooks, and the manner of their final resolution will not be of indifference in these areas. Was the universe created, or not? Is there a "creator" God, or not? These and allied questions represent the "final set of implications" of the physical hypotheses involved, and history again suggests that perhaps these areas of mutual discourse should not be separated. Let us turn now to the direct historical roots of the second law, which start with Newton's work and thoughts, and carry forward into the nineteenth century.

CHAPTER III

ANTICIPATION OF THE SECOND LAW; NEWTON, BENTLEY AND WHEWELL

William Thomson (Lord Kelvin) announced the second law in England in the 1850's. Although the form which Kelvin gave to it was unique, the law was to a degree a systhesis of the work of several other men. Among these, Kelvin recognized the previous contributions of Carnot, Fourier, and Joule as bearing on his formulation. Carnot had contributed the idea of an ideal heat engine working cyclically through the "fall" of heat from a higher to a lower temperature. However, Carnot had stated his idea within the framework of the Caloric theory of heat, which maintained (incorrectly) that heat was a fluid which was conserved. James P. Joule had contributed the idea that heat per se was not conserved, rather it was only a particular form of energy, convertible into mechanical motion and vice versa (Kelvin: 1894:19). Kelvin recast the Carnot relationship in terms of Joule's conservation and convertability of energy concepts. In addition, Kelvin relied upon and made use of the Fourier equations of heat flow (Thompson: 1910:111) and frequently referred to them when talking of the second law. All of these ideas formed parts of the puzzle, fitting together to form the second law as a generalization.

Several other sources of inspiration on the second law existed, however, which were apparently known to Kelvin. These sources were the cosmological speculations of Issac Newton and Richard Bentley in the

1690's and William Whewell in the first third of the nineteenth century.[1] All three were Cambridge men, as was Kelvin; all were influential. Newton was the undisputed scientific genius of seventeenth-century Cambridge; his work and thoughts were usually regarded, there and elsewhere, with reverence. Bentley,[2] admitted to Cambridge as a child prodigy at the age of fourteen, became an eminent scholar with scientific interests, and later was for forty-two years Master of Trinity College at Cambridge. Whewell, approximately a century later, distinguished himself both as moral philosopher and physicist at Cambridge. The recorded thoughts of these three men are part of the Cambridge tradition in scholarship, and their religiously inspired speculations in cosmology, which together strikingly suggest Kelvin's later statement of the second law, also conform to the Cambridge outlook in those days of seeing the world as the handiwork of the Lord.

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[1]For example, in his Popular Lectures and Addresses (1894:538) Kelvin cites the correspondence of Newton and Bentley; in that same work he also has reference to Whewell (1894:540).

[2]Most readers will probably be unfamiliar with Richard Bentley. In The Correspondence of Issac Newton (1961:156) H. W. Turnbull notes:

> Richard Bentley (1662-1742), scholar and critic, graduated from St. John's College, Cambridge, and after holding several posts became Master of Trinity College, Cambridge (1700-42). He delivered the first course of Boyle Lectures, taking for his subject "A Confutation of Atheism' (1692); while Keeper of the King's Library housed at St. James's Palace he founded a discussion club that included Wren, Locke, Newton and Evelyn (c. 1697). At Trinity College he had erected on the roof of the great gate the first observatory in Cambridge and established a chemical laboratory in the medieval chambers overlooking the Bowling Green. He was a supreme classical scholar, strong administrator and caustic wit, of whom one of his successors, two hundred years later, wrote: 'But if ever man was Master of Trinity, it was he. . . . His fame is ours. And in the world of scholarship that fame stands higher than that of any other Trinity man--except immortal Newton' (G.M. Trevelyan, Trinity College (1943)).

Kelvin drank deeply of the Cambridge tradition while a student and later a Peterhouse fellow, and his years there were also those in which he developed and formulated the second law. (Kelvin's announcement of the second law, published in a series of articles in the London, Edinburgh, and Dublin Philosophical Magazine, July through December, 1852, came in the last year of his Peterhouse fellowship.) To some degree, the influence of the thoughts of Newton, Bentley and Whewell upon Kelvin remains conjectural. Kelvin did a great deal of independent reading and thinking while a student, and was familiar with the works of these men. He actively sought to find and develop some great ideas, and often tended to neglect formal studies in favor of his independent readings, which were far-reaching. He intended to make his mark, saying to a friend, "The well-taught, well trained, and at the same time clever man is <u>the</u> man for Cambridge" (Thompson: 1910:40). Newton was undoubtedly an influence in his life. In this regard, Thompson (1910:1013-15) relates the following:

> He (Kelvin) had, in fact, set before himself very early in his career an immensely high ideal, a noble ambition of so tremendous an import that it would seem as if all his life he had shrunk from exhibiting it in full panoply. Yet there had assuredly haunted him day by day the suggestion of an all-embracing, comprehensive theory of matter. In the preface to Newton's Principia, the great philosopher . . . uttered the aspiration: Utinam caetera Naturae phaenomena ex principiis Mechanicis eodem argumentandi genere derivare liceret. That pregnant sentence might well be the symbol of Lord Kelvin's intellectual career. . . .
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> To be the Newton of the molecular theory which should afford a dynamical explanation of all these properties was a noble and worthy ambition. Such an idea seems to have come to William Thomson in a partial aspect during the spring of 1846, while he was still at Peterhouse. . .

Again, Thompson (1910:1145) relates:

> . . . Lord Kelvin's mathematical method greatly resembled that of Newton. . . In this Lord Kelvin belonged essentially to the school of Newton in which he had been trained. His reverence for Newton was not merely the veneration felt for an honored

name; it was a living devotion to the genius of the creator of the British school of Natural Philosophy.

It is to the thoughts of Whewell, Bentley and Newton, regarding what has come to be called the second law, that we turn in this chapter. In these thoughts, particularly those given by Newton, the entire area of natural processes now covered by the second law appears as a continent yet to be charted, and an area, moreover, where the direct action of the Lord God might be revealed. Before examining these thoughts, let us look at the 1852 statement of the second law by Kelvin, as well as one other comment of his, so that Kelvin's conception may be compared to the ones we shall be examining. Kelvin's statement of the second law in the Philosophical Magazine (1852:304-306) is given below:

> XLVII. On a Universal Tendency in Nature to the Dissipation of Mechanical Energy. By Prof. W. Thomson
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> The object of the present communication is to call attention to the remarkable consequences which follow from Carnot's proposition, that there is an absolute waste of mechanical energy available to man when heat is allowed to pass from one body to another at a lower temperature, by any means not fulfilling his criterion of a "perfect thermo-dynamic engine," established, on a new foundation, in the dynamical theory of heat. As it is most certain that Creative Power alone can either call into existence or annihilate mechanical energy, the "waste" referred to cannot be annihilation, but must be some transformation of energy.

(Some mathematical and physical arguments follow, and then:)

> The following general conclusions are drawn from the propositions stated above, and known facts with reference to the mechanics of animal and vegetable bodies:--
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> 1. There is at present in the material world a universal tendency to the dissipation of mechanical energy.
>
> 2. Any restoration of mechanical energy, without more than an equivalent of dissipation, is impossible in inanimate material processes, and is probably never effected by means of organized matter, either endowed with vegetable life or subjected to the will of an animated creature.
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> 3. Within a finite period of time past the earth must have been, and within a finite period of time to come the earth must again be, unfit for the habitation of man as at present constituted, unless operations have been, or are to be performed,

> which are impossible under the laws to which the known operations going on at present in the material world are subject.

The last phrase of this formulation, ". . . unless operations have been, or are to be performed, which are impossible under the laws. . ." appears to be open; to imply something more. What it implied for Kelvin can be seen in the comment which he added in 1862 to his customary introductory lecture on physics at Glasgow (Thompson: 1910:241): "The fundamental subject of Natural Philosophy is Dynamics, or the science of force. . .(which). . .shows that the inanimate world must have had a beginning, and that all motion except that of heat must have an end, unless it please God to restore by an act of new creative power the dissipation of mechanical effect which always goes on." The main concept for comparison with the ideas of Newton, Bentley and Whewell is apparent: the nature of the physical (inanimate) world requires God's action in the past, and perhaps again in the future, if it is to be (or remain) a going mechanical concern.

Newton and Bentley

Cosmological speculation in Newton's time was an unstable mixture of materialistic and theistic assumptions. The Democritean hypothesis of the eternity of matter was held by a number of thinkers, and something like a precursor to Laplace's nebular hypothesis had been developed upon Lucretius' interpretation of atomism. Supposing a primordial chaos of atoms spread randomly through space, said Lucretius,

> ...It comes to pass that those primordials (atoms),
> Diffused far and wide through mighty aeons,
> The while they unions try, and motions too,
> Of every kind, meet at the last amain,
> And so become oft the commencements fit
> Of mighty things--earth, sea, and sky, and race
> Of living creatures.
>
> (Brinton, 1961:52)

Against this naturalistic approach the theological outlook held that even if matter was supposed to be eternal, it could in no way set itself in motion, nor could it order itself through 'fortuitous concorse of atoms.' Motion, order, design, were impressed by the deity; such action was in fact His prerogative alone. In Newton's words (Newton to Bentley, 25 February 1692/3, from Turnbull, Vol. III, 1961:253) matter was "inanimate brute matter," incapable "without ye mediation of something else wch is not material," of producing the visible world. The letters between Newton and Bentley in 1692/3 were initiated by Bentley, who was at that time chaplain and prebendary to the Bishop of Worcester, and who was preparing to deliver a series of lectures entitled "A Confutation of Atheism." The lectures, established at the bequest of Robert Boyle, dwelt heavily on physical science as a source of evidence for the theological outlook; Bentley turned to Newton for advice in their preparation. The thrust of these lectures turned, not on the eternity of matter per se but rather upon whether matter alone could have produced the present system of the world. Along this line of thought Bentley had written to Newton (Turnbull, Vol. III, 1961:246ff):

> Proved, in ye 6 sermon That ye present System of ye world cannot have been eternal. So yt matter being eternal (according to ye Atheists) All was once a Chaos, yt is, all matter was evenly or nearly upon evenly diffused in the mundane spaces. I proceed therefore . . . to shew, yt matter in such a chaos could never naturally convene into this or a like System. . . . Mechanism or power of inanimate Matter . . . must proceed from a higher principle and a divine energy and impression.

Newton's replies to Bentley's questions are of considerable interest, as he frankly sets forth views restrained in his own published works.

Newton's unique position as supreme scientist in the England of his day is relevant to his position in the above letters. Newton's own work had immensely enlarged the domain of natural causation; indeed, the

'Newtonian world-machine' was later to become hard currency for materialism. Yet Newton himself was deeply religious; nothing could be further from his desires than such an outcome. In the words of Burtt (1954:286) Newton "approached the world of science under the necessity of seeing it cloaked by a divine glory and suffused with the religious significance that followed from the conviction that it had been created and ordered by the hands of the God who had been worshipped from his youth as Father of the Christian Saviour and infallible Author of the Christian Scriptures."

And so, Newton replied to Bentley's request for advice, saying (Turnbull, Vol. III, 1961:233): "Sir; When I wrote my treatise about our Systeme I had an eye upon such Principles as might work with considering men for the beleife of a Deity & nothing can rejoyce me more than to find it usefull for that purpose." The correspondence which ensued covered a number of physical concepts, including the question as to whether Gravity is 'innate' to matter and whether the planets could have been placed in their orbits by natural processes, whether "old systems cannot gradually wast & pass into new ones . . . from ye exhaling matter of former decaying systems. . .", and so forth. On this last idea, Newton commented (Turnbull, Vol. III, 1961:253), ". . . ye growth of new systems out of old ones without ye mediation of a divine power seems to me apparently absurd." On the motions of the planets, he commented (Turnbull, Vol. III, 1961:244), ". . . the transverse motions by wch they revolve in their several orbs required the divine Arm to impress them according to ye tangents of their orbs." He went on to say, "I would now add that the Hypothesis of matter being at first evenly spread through the heavens is, in my opinion, inconsistent wth ye Hypothesis of innate gravity, without a supernatural power to reconcile them, & therefore it infers a Deity." Further, Newton appears to have seen gravity as not innate to matter, but rather as "ye mediation of something else wch is not material. . . ." In Newton's thought, God had a very present role of continuing action in the universe. Considering the works of Newton, Burtt (1954:293) reaches the same conclusion:

> Now from Newton's writings, as from Boyle's, it is possible to pick passage after passage in which it seems to be assumed that after its first construction the world of nature has been quite independent of God for its continued existence and motion. But when we investigate more thoroughly we find that he, no more than Boyle, had any intention of really divorcing God from present control of, and occasional interference with, his vast engine. It is not enough to have the miracles of scripture and the achievements of spiritual grace to appeal to as evidences of continued divine contact with the realm of human affairs. God must also be given a present function in the cosmos at large; we must not allow him to abandon his toils after six days of constructive labour and leave the world of matter to its own devices. Newton's religious prejudices and his aesthetico-scientific assumptions alike arose in rebellion against such an indeterminate vacation for the Deity.

It is along the above lines of discovering work for the Deity in the physical world that R. E. D. Clark (1961:19) sees in Newton's letters to Bentley an early statement of the second law. Clark says:

> . . . a recognition of the idea is to be found quite clearly expressed in the writings of Newton. In his well-known Letters to Bentley, Newton points out that hot objects always warm cold ones until the two are at the same temperature. But the universe, he says, contains hot and cold bodies which have not, apparently, had time to reach thermal equilibrium. It follows that such a state of affairs cannot have existed forever . . . The universe could not, therefore, be explained on materialistic lines but must have been made by God.

It is curious, but this writer cannot discover such a passage in the Newton-Bentley correspondence. Clark footnotes "Brewster's Life of Newton (Vol. II, p. 125ff.)." In summarizing these letters, Brewster likewise makes no such discovery. In his letter of 10 December 1692, Newton does comment on the creation of a radiant sun and opaque (cold) planets but presents this as an argument for creative design (Turnbull, Vol. III, 1961:234). However, this same letter ends with the following enigmatic statement: "There is yet another argument for a Deity wch I take to be a very strong one, but till ye principles on wch tis grounded be better received I think it more advisable to let it sleep. I am Your most humble Servant to command, Is. Newton." (--A tantalizing comment. Is Newton, after all, alluding to the thermodynamic argument?)

It is possible, by going to Newton's Optics (1721:372ff) to place such a construction on the matter. There Newton comments:

> The vis inertiae is a passive principle by which bodies persist in their motion or rest, receive motion in proportion to the force impressing it, and resist as much as they are resisted. By this principle alone there never could have been any motion in the world. Some other principle was necessary for putting bodies into motion; and now they are in motion, some other principle is necessary for conserving motion. For from the various composition of two motions, 'tis very certain that there is not always the same quantity of motion in the world. . . . it appears that motion may be got or lost. But by reason of the tenacity of fluids, and attrition of their parts, and the weakness of elasticity in solids, motion is much more apt to be lost than got, and is always upon the decay.
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> Seeing therefore the variety of motion which we find in the world is always decreasing, there is a necessity of conserving and recruiting it by active principles, such as are the cause of gravity, by which planets and comets keep their motions in their orbs, and bodies acquire great motion in falling; and the cause of fermentation, by which the heart and blood of animals are kept in perpetual motion and heat; the inward parts of the earth are constantly warmed, and in some places grow very hot; bodies burn and shine, mountains take fire, the caverns of the earth are blown up, and the sun continues violently hot and lucid, and warms all things by his light. For we meet with very little motion in the world, besides what is owing to these active principles. And if it were not for these principles the bodies of the earth, planets, comets, sun, and all things in them would grow cold and freeze, and become inactive masses; and all putrefaction, generation, vegetation, and life would cease, and the planets and comets would not remain in their orbs.

The above passage is a rather striking intimation of the 'heat death' hypothesis. On it Burtt (1954:267) comments: "To his (Newton's) mind, the world of matter appeared a very imperfect machine; motion was everywhere on the decay."

If the thermodynamic arguments for divine action do not spring in fully developed form from Newton's speculations, still, the format for such argument is clearly present, and heat and cold are seen to be involved.

Newton's view that God had an active and continuing role, both as creator and preserver of the universe in the efficient or mechanical sense, provoked a rather frank[3] commentary from Leibnitz on the Continent, sent by letter to the princess of Wales in November 1715. The letter, in part, follows below (Brewster, Vol. II, 1965:284):

> Sir Isaac Newton and his followers have also a very odd opinion concerning the Work of God. According to their doctrine, God Almighty wants to wind up his watch from time to time, otherwise it would cease to move. He had not, it seems, sufficient foresight to make it a perpetual motion. Nay, the machine of God's making is so imperfect according to these gentlemen, that he is obliged to clean it now and then by an extraordinary concourse, and even to mend it as a clockmaker mends his work; who must consequently be so much the more unskilful a workman, as he is oftener obliged to mend his work, and to set it right. According to my opinion the same force and vigour remains always in the world, and only passes from one part of matter to another, agreeably to the laws of nature and the beautiful pre-established order. And I hold that when God works miracles, he does not do it in order to supply the wants of nature, but those of grace. Whoever thinks otherwise, must needs have a very mean notion of the wisdom and power of God.

The respective positions of Leibnitz and Newton on this point in cosmology represent well the two religious viewpoints discussed in chapter

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[3]The forthright tone of this letter in part derives from the controversy then going on as to who had discovered the Calculus first; Newton or Leibnitz. In actuality, the discovery was independent and virtually simultaneous as between the two men. The above letter was sent as a challenge to Newton, and indeed, the King himself requested that Newton prepare a response. Later, Edward Clarke was substituted as defender of the English faith, while Newton prepared the defense on his invention of his form of the calculus. For Clarke's replies to Leibnitz, see Dr. Clarke's Works, 1738, Vol. IV, pp. 580-710.

one. In Leibnitz' view, the universe is a 'perfect work', and hence a perpetual motion; "the same force and vigour" remain always in it. Newton's theological view, on the other hand, may be clearly seen in a passage from the Optics (1721:381). Considering the nature of God, Newton says:

> This Being governs all things, not as the soul of the world, but as Lord over all; and on account of his domination he is wont to be called Lord God or Universal ruler . . . a being, however perfect, without dominion, cannot be said to be Lord God . . . And from his true dominion it follows that the true God is a living, intelligent, and powerful being . . . and a god without dominion, providence, and final causes, is nothing else but Fate and Nature.

"Absurd indeed, it would be," comments Burtt (1954:294), "to deprive a being so portrayed of present control of his creation; accordingly we find Newton assigning to God . . . very important and specific duties in the daily cosmic economy." Returning to Kelvin's comment quoted earlier, "that all motion except that of heat must have an end, unless it please God to restore by an act of new creative power the dissipation of mechanical effect which always goes on," one can see a partial parallel of the theological and physical thoughts of Newton which we have examined. However, it is not possible to say that the above thoughts constitute the only path of inspiration from Newton. If one considers Newton's work rather than his theological outlook, one finds no formal recognition of a natural, irreversible decay; Newtonian mechanics is reversible. Within its scope the world may well be a perpetual motion. Recall further that when Newton dwelt upon the action of heat and cold, he referred to "active principles." At times he used this phrase to allude to God's action, but it may also refer to principles in the sense of natural laws. Newton actually speculated upon both natural and divine replenishment of systems. On this point, More (1934:663) relates a conversation between Newton and Conduitt in 1724, near the close of Newton's life. The conversation was related by Conduitt; during its course Newton conjectured that the heavenly bodies were periodically subject to decay and replenishment, and that the vapours and light emitted by the sun "gathered themselves by degrees into body, and attracted more matter from the planets; and at last became a comet, which after certain revolutions, by coming nearer and nearer the sun, had all its volatile parts condensed, and became a matter fit to recruit, and replenish the sun, which must waste by the constant heat and light it emitted." This idea is essentially cyclical replenishment powered by gravity. Yet at the same time Conduitt relates, "He (Newton) seemed to doubt whether there were not intelligent beings superior to us, who superintended these revolutions of the heavenly bodies, by the direction of a Supreme Being." (This latter idea follows Plato's Timaeus.) More relates, "The conversation closed by Conduitt wishing to know why he (Newton) would not, in the Principia, acknowledge that the sun was replenished and recruited by comets dropping into it, when he had made a similar statement about the fixed stars. 'He said that concerned us more; and laughing, added that he had said enough for people to know his meaning.' Such were the last recorded thoughts of Newton on the world system, whose laws he had done so much to discover; and it is well to remember that he had said of himself: 'I kept an eye upon such principles as might work with considering men for the belief of a Deity. . .'"

Two very different possible lines of development seem to lead from Newton; on the one hand natural, on the other supernatural regeneration of the world. But in Newton's mind, the "active principle" is present in the world in either case. Kelvin may well have been inspired by him, but one difference is immediately apparent. Kelvin's orthodoxy outstrips Newton's; in Kelvin's view, God has acted creatively in the past, and may act again in the future; but the world is now in a process of energy dissipation, not counterbalanced by present action, either natural or divine. Kelvin's views follow from only one (and that the more orthodox) side of Newton's thought.

William Whewell

From Newton's century onward into Kelvin's, the association between orthodoxy in British religion and science remained strong, indeed dominant in strongholds such as Cambridge; that orthodoxy in turn continued to demand that the world be seen as the 'handiwork of the Lord.' Writing on the early part of this period, Merton (1968:629ff) notes:

> The puritan ethic, as an ideal-typical expression of the value-attitudes basic to ascetic Protestantism generally, so canalized the interests of seventeenth century Englishmen as to constitute one important element in the enhanced cultivation of science. The deep-rooted religious interests of the day demanded in their forceful implications the systematic, rational and empirical study of nature for the glorification of God in His works and for the control of the corrupt world . . . if nature is the manifestation of His power, then nothing in nature is too mean for scientific study. . . . Macrocosm and microcosm alike, are indications of 'divine reason', running like 'a Golden Vein through the whole leaden Mine of Brutal Nature.'

Merton goes on to note another important stronghold of this outlook, the Royal Society, an association of distinguished scientists which had the patronage of the king, beginning with its inception in 1645. Bentley and Newton had been members, as well as being Cambridge men; William Whewell, working in the first third of the nineteenth century and a contemporary of Kelvin, is another representative of this background. Whewell championed the more theological side of Newton's work. In his History, and in his Philosophy of the Inductive Sciences (1840) as well as in his Philosophy of Discovery (1856) he argued that all branches of science pointed to a past Creation at the hands of God. In his Astronomy and General Physics contribution to The Bridgewater Treatises (1836) he advanced a theory of "the universal law of decay" which appears to be a close qualitative forerunner to Kelvin's law of universal "dissipation" in 1852. We shall look at several passages from these works.

To be set in its historical context, however, Whewell's line of thought needs to be compared to that given by the materialistic outlook in science, which since the time of Newton had been gaining ground, and gaining it, moreover, precisely upon the foundations which Newton had laid in support of his religious outlook. As Dampier (1950:175) put it, "The 'most beautiful System of the Sun, Planets and Comets,' which to Newton could only proceed from a beneficent Creator, was used in the eighteenth century as the basis for a mechanical philosophy, and replaced the atomism of the ancients as the starting point of an atheistic materialism." This movement gained considerable dominance in France, and found particular fruition in The System of the World (1796) and the Mecanique Celeste (1799-1805) of Pierre Simon Laplace. Laplace developed and advanced the Nebular Hypothesis, at the same time fusing it to the ideas advanced in Newton's Principia (Dampier, 1950:180). To those of the theological outlook, such fusion was blasphemy. The nebular hypothesis was "the dull and dangerous heresy of the age" (Brewster, Vol. II, 1965:131).

Yet Laplace had tackled Newton's theology head on, commenting in his System of the World (1796; Eng. Tr. 1830:332ff):

> A blind fate, says he (Newton), 'could never make all the planets to move thus. . .' But could not this arrangement of the planets be itself an effect of the laws of motion; and could not the supreme intelligence which Newton makes to interfere, make it

> depend on a more general phenomenon? such as, according to us, a nebulous matter distributed in various masses throughout the immensity of the heavens? . . . If we trace the history of the progress of the human mind, and of its errors, we shall observe final causes perpetually receding, according as the boundaries of our knowledge are extended.

Laplace's next words are of interest as reflecting on the difference between the three analytic categories developed in chapter one. Newton, he says, believes that there are

> . . . some irregularities, hardly perceivable, which may arise from the mutual action of the planets and of the comets, and which, probably, in the course of time will become greater, til in fine the system may require to be restored by its author. . . Leibnitz, in his controversy with Newton . . . attacks him with great force on account of his introducing the divinity to restore order into the solar system. 'It is,' says he, 'to have too confined notions of the wisdom and power of the deity.' Newton rejoined by an equally severe critique on the preestablished harmony of Leibnitz, which he designated a continual miracle. Subsequent ages have not admitted these vain hypotheses; they have, however, rendered the most ample justice to the mathematical labours of these two great men; the discovery of universal gravitation, and the efforts of its author to explain all the heavenly phenomena by means of it, will for ever secure to him the admiration and gratitude of posterity.

Note what has happened here: Newton has rejected Leibnitz' theology and Leibnitz, Newton's; Laplace rejects them both and recruits with praise Newton's work in the advancement of the materialist view.

Laplace's System of the World was a popular rather than a technical work; as Dampier relates (1950:180), "Laplace's analytical discussion was given in his larger work, the Mecanique Celeste, in which he translated the substance of Newton's Principia into the language of the infinitesimal calculus, and completed it in many details. Dampier follows with a brief account from Rouse Ball of the celebrated meeting between Laplace and Napoleon after the completion of the Mecanique Celeste: "Someone had told Napoleon that the book contained no mention of the name of God; Napoleon, who was fond of putting embarrassing questions, received it with the remark, 'M. Laplace, they tell me you have written this large book on the system of the universe, and have never even mentioned its Creator.' Laplace . . . drew himself up and answered bluntly, 'Je n'avais pas de besoin de cette hypothese-la.' That phrase has been repeated sufficiently often by historians of science to stand as the capsule position of the materialist; it also constitutes the ultimate insult to the scientist convinced with his whole being that his work is a form of worship. Thus matters stood in Whewell's time; the devout style of physics in England remained strong, but materialism had been gaining much ground; it was 'a present danger.' Whewell forthrightly enlisted his view of science to the traditional religious outlook, and it is to this view that we next turn.

In the following passage from The Philosophy of the Inductive Sciences (Vol. II, 1840:585) Whewell, quoting Newton, expresses the following outlook:

> And thus, in concluding our long survey of the grounds and structure of science, and of the lessons which the study of it teaches us, we find ourselves brought to a point of view in which we can cordially sympathize . . . We can . . . not only say with Newton that 'every true step made in philosophy brings us nearer to the First Cause, and is on that account to be highly valued;' -- and that 'the business of natural philosophy is to deduce causes from effects, till we come to the very First Cause, which is certainly not mechanical:' --but we can go much further, and declare, still with Newton, that 'this beautiful system could have its origin no other way than by the purpose and command of an intelligent and powerful Being, who governs all things, not as the soul of the world, but as the Lord of the Universe; who is not only God, but Lord and Governor.

This was the conclusion, he said, ". . . to which our Philosophy points with trembling finger and shaded eyes." But how to establish such a conclusion physically? Material, causal systems must be seen to converge to an origin, a Creation, and to lead as in the biblical account to an end. Along this line of thought, Whewell gave, in The Bridgewater

Treatises (Treatise III, 1836:110ff) his statement of "the universal law of decay":

> . . . The forest tree endures for its centuries and then decays; the mountains crumble and change, and perhaps subside in some convulsion of nature; the sea retires, and the shore ceases to resound with the "everlasting" voice of the ocean: such reflections have already crowded upon the mind of the geologist; and it now appears that the courses of the heavens themselves are not exempt from the <u>universal law of decay</u>; that not only the rocks and the mountains, but the sun and the moon have the sentence "to end" stamped upon their foreheads. They enjoy no privilege beyond man except a longer respite. The ephemeron perishes in an hour; man endures for his threescore years and ten; an empire, a nation, numbers its centuries, it may be its thousands of years; the continents and islands which its dominion includes have perhaps their date, as those which preceded them have had; and the very revolutions of the sky by which centuries are numbered will at last languish and stand still. . . . The smaller portions of matter which we have near us, and the larger, which appear as luminaries at a vast distance, differ as they are in our mode of conceiving them, obey the same laws of motion; and these laws produce the same results; in both cases motion is perpetually destroyed, except it be repaired by some living power; in both cases the relative rest of the parts of a material system is the conclusion to which its motion tends. . . <u>To maintain either the past or the future eternity of the world, does not appear consistent with physical principles, as it certainly does not fall in with the convictions of the religious man, in whatever way obtained. We conceive that this state of things has had a beginning; we conceive that it will have an end.</u>
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> (emphasis supplied)

Whewell goes on to posit the ether as a resisting medium, which must gradually slow and finally stop all motion of the heavenly bodies, and then turns to confront the Nebular hypothesis: "Thus the argument which was before urged against those in particular, who put forwards the Nebular Hypothesis in opposition to the admission of an Intelligent Creator, offers itself again, as cogent in itself, when we adopt the opinion of a resisting medium, for which the physical proofs have been found to be so strong."

Yet for all Whewell's argument, the central idea has not been advanced beyond Newton's time. In The Philosophy of Discovery (1856:382ff), Whewell takes up again this line of thought which has been his constant theme, and it is again clearly suggestive but not definitive. Whewell comments:

> Acknowledging a divine mind which is the foundation and support of the world as it is, constituting and upholding its laws, it may be asked, Does this view point to a beginning of the world? Was there a time when the Divine Mind called into being the world, before non-existant? Was there a creation of the world?
> . . . In point of fact, every part of our knowledge of the Universe does seem to point to a beginning . . . But we must allow, on the other hand, that though all such lines of research point <u>towards</u> a beginning, none of them can be followed <u>up to</u> a beginning. All the lines converge, but all melt away before they reach the point of convergence. . . .
> But if our natural reason, aided by all that science can teach, can tell us nothing respecting the origin and beginning of this world, still less can reason tell us anything with regard to the <u>End</u> of this world . . . (but) . . . it would not be at all impossible that physical inquiries should present the prospect of an End, even more clearly than they afford the retrospect of a Beginning.

These suggestive phrases, uttered by a contemporary of Kelvin's, who was, moreover, a distinguished professor at Cambridge during Kelvin's student years, seem clearly to foreshadow both the direction of Kelvin's thought, and his conclusions. Let us turn to a consideration of Kelvin.

CHAPTER IV

KELVIN AND THE SECOND LAW

Kelvin's statement of the second law in the 1850's may be viewed as a purely physical generalization from known facts which holds that all material transformations are, in the net, leveling processes. The law is so presented in the majority of physics texts. However, seen in its historical context, the law seems to be less a law and more of a daring, interpretative extrapolation from selected facts, designed to be a contender in the running cosmological debates of its time. Those debates focused around two major positions; the Newtonian-theological and the Laplacean-materialistic. Since Newton's time, the materialistic position had been steadily gaining ground.[1] On the other hand, the

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[1]Burtt (1954:298) summarizes this advance as follows:

> Really, the (Newtonian) notion of the divine eye as constantly roaming the universe on the search for leaks to mend, or gears to replace in the mighty machinery would have been quite laughable, did not its pitifulness become earlier evident. For to stake the present existence and activity of God on imperfections in the cosmic engine was to court rapid disaster for theology. . .
>
> Science moved on, and under the guidance of the less pious but more fruitful hypothesis that it would be possible to extend the mechanical idea over an ever wider realm, Newton's successors accounted one by one for the irregularities that to his mind had appeared essential and increasing if the machine were left to itself. This process of eliminating the providential elements in the world-order reached its climax in the work of the great Laplace, who believed himself to have demonstrated the inherent stability of the universe by showing that all its irregularities are periodical, and subject to an eternal law which prevents them from ever exceeding a stated amount . . . In short, Newton's cherished theology was rapidly peeled off by all the competent hands that could get at him.

Newtonian-theological outlook continued to be championed -- particularly in England. William Whewell's comments given in the last chapter typify that outlook. Yet there was an essential difference between the scientific-religious concepts of Newton and those propounded by Whewell. Newton's God was an active God. Whewell, retrenching in the face of advancing materialism, emphasized divine activity in the past. As a result the universe, that mighty machine of His creation, was now decaying on the grand scale. Without plumbery or pluggery its decay pointed backward to one great beginning. Whewell had seen "every part of our knowledge of the universe" as pointing to that beginning. Yet, he said (1971:383) ". . . none of them can be followed <u>up to</u> a beginning."

Consider now the theoretical effects of Kelvin's statement of the second law. It appeared to lead all the way up to that beginning. It appeared supportative of Newton's theology and was at the same time a very successful, mathematically quantitized synthesis of Newtonian mechanics and heat flows. It was a genuine advance; in baseball terms, a three-bagger, <u>possibly</u> the winning home run. It was at that time no more speculative than the nebular hypothesis, and it appeared to throw a net of ultimate limits around the process of unending material causation at the heart of that hypothesis. In short, it drew all lines of causation backward to a single Gordion knot -- Creation.

Whether rightly or wrongly, this is how the second law was perceived at that time, and how it was presented by Kelvin. Let us turn to the relevant biographical elements surrounding Kelvin's development of the second law.

Kelvin's Boyhood

James Thomson, Kelvin's father, was of Scottish extraction, coming from a County Down farming family. During his early years, he studied for the Established (Presbyterian) Church of Scotland ministry, but discovered another calling -- mathematics. As a man he occupied the chair in mathematics at Glasgow College, and his son William (Kelvin) grew up in the atmosphere of that old college. James Thomson, much like John Stewart Mill's father, took an active interest in the education of his son, an education which was begun at home at an early age. As Grey (1973:8) relates, the father "was a stern disciplinarian, and did not relax his discipline when he applied it to his children, and yet the aim of his life was their advancement." He instilled in his son William a deep yet simple religious outlook which Kelvin was to make uniquely his own. Thompson (1910:1089) relates that "As a young man he (Kelvin) had thought things out in his own way, and had come to a faith which . . . being of personal conviction, was never afterwards shaken. His faith was always of a very simple and child-like nature . . . It pained him to hear crudely atheistic views expressed by young men who had never known the deeper side of existence."

James Thomson also kindled in William a passion for mathematics and a deep determination to distinguish himself. William's father entered him, at the age of ten, in Glasgow College, where he studied, excelling particularly in his father's mathematics courses, until at the age of seventeen he had completed the requirements for an undergraduate degree. Then, in 1840, he made undergraduate application to Cambridge, not filing for his Glasgow degree so as not to prejudice his admission to Cambridge.

The Cambridge Years

The period 1840-1841 witnessed the following events: Kelvin completed his Glasgow work, and during a summer vacation with his father and older brother in Germany, enthusiastically read Fourier's Theorie Analytique de la Chaleur, which he considered 'mathematical poetry.' Upon returning to England, he published, under a pseudonym, an article in the Cambridge Mathematical Journal vindicating Fourier's work from the charges of error which had been made by a British mathematician. This article created a bit of a stir in British mathematical circles, and when Kelvin entered St. Peter's College, Cambridge, in the fall of 1841, he was already viewed as a student of promise.

He brought to Cambridge his talent, ambition, and a religious and mathematical outlook in certain ways fused. In later life he expressed in his classes the obiter dicta, "Mathematics is the only true metaphysics" (Thompson, 1910, Vol. II:1124). Again, Thompson reports (1910, Vol. II:1140) ". . . he spoke of those who 'have the <u>privilege</u> which high mathematical attainments confer.'"

In the summer of 1842 he prepared a paper for the Cambridge Mathematical Journal entitled, "On the Linear Motion of Heat." This seems to have been a germinal paper with regard to the second law, and Thompson's comments on it are of interest. Thompson (1910, Vol. II:42-43) states that the paper

> . . . gave the solution in two different forms of the differential equation which expresses the linear motion of heat in an infinite solid, by which equation it is sought to find the temperature at some point at any distance, x, from a given zero-plane at any time t. This paper was a mathematical development of some intricacy on the lines of Fourier's work.
>
> Again and again in later years Lord Kelvin would return to this paper as containing the germs of many of his subsequent ideas. In its concluding passage it contained a speculation as to the inference to be drawn if negative values are assigned to

> the time t; for obviously the theorems laid down hold good for negative values of t, as well as for positive values. In general it resulted that the temperature of any plane except the zero plane will be impossible for negative values of t; since the initial distribution of heat, assumed in the function, is in general not of such a form as to constitute any stage, except a first stage, in a possible system of varying temperatures. In other words, the state represented cannot be the result of any possible anterior distribution of temperature. Lord Kelvin used to declare that it was this mathematical deduction which convinced him that there must have been an origin to the natural order of the cosmos; that therefore natural causes could not be deduced backwards through an infinite time. There <u>must</u> have been a beginning.

Kelvin's idea that the Fourier equations predicted an "origin to the natural order of the cosmos" is of interest. Those equations describe the change in the distribution of heat in a body as that body cools. Traced backward to a certain point or original condition of the system the equations are valid, but carried backward past that point in time they give "impossible" values. One may make two decisions in the case: a) that the equations as given have ceased to be useful in describing the physical system to which they were applied, or b) that the equations imply something physically unique. If one tends to view mathematics as "the only true metaphysics",[2] one might make the latter interpretation. In the next chapter we shall look at a critique of the "Origin" argument from the Fourier equations which was given by W. K. Clifford, who held that what was implied by backward extrapolation of the equations was no more than a probable change of state of the natural system, and our ignorance of that change of state, unless further empiric information could be obtained. It is important to bear in mind, however, that Kelvin

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[2]Merton (1968:633) notes that the Puritan scientific outlook which Kelvin along with many other Englanders shared, "was suffused with the rationalism of neo-Platonism." In this neo-Platonic outlook, rational, mathematical forms were seen as having metaphysical reality and metaphysical implications.

assumed the metaphysical interpretation and stuck with it.

During the years 1841-43 while Kelvin was studing at Cambridge, he read Laplace's Mecanique Celeste and Lagrange's Mecanique Analytique. Grey (1973:19) reports that they "made a deep impression on the mind of the youthful philosopher." During this period Kelvin read widely, and it seems to have been during these years that he became acquainted with the correspondence and other works of Newton, as well as with the thoughts of Whewell, who was teaching at Cambridge at the time. The English tradition of devout science exemplified by Newton, and the materialistic tradition exemplified by Laplace, must have presented themselves to Kelvin; providing a choice point for his own developing position. That position became, throughout his life, an advocacy of devout science accompanied by active criticism of materialism.

Kelvin, The Glasgow Professor of Natural Philosophy

By 1845, Kelvin had made his mark at Cambridge. He had published sixteen papers, mostly in the Cambridge Mathematical Journal, the majority of which were on the subject of heat. In 1845-46 he took his graduation examinations, coming out second wrangler and first Smith's Prizeman. It was during these last few years at Cambridge that Thompson relates he began to get the idea of becoming the Newton of the molecular theory (1910:1015).

In September 1846, at the age of twenty-two, Kelvin was elected to the chair of Natural Philosophy at Glasgow; a position which he retained for the rest of his life. His Inaugural Dissertation, 'De Motu Caloris per Terrae Corpus' (delivered in Latin) set forth the position which he later maintained toward the theory of geological uniformitarianism; i.e., that it was wrong. Gray (1973:65) relates that the paper

". . . gave a very decisive limitation to the possible age of the earth as a habitation for living creatures; and proved the untenability of the enormous claims for TIME which, uncurbed by physical science, geologists and biologists had begun to make and to regard as unchallengeable."

At Glasgow College, Kelvin did his teaching. King (1925:29) relates: "He always began his class in college with prayer, and chose the third Collect for Grace from the Church of England service . . . there was something in his humble and quiet reverence which seemed to strengthen one's own faith and bring one directly into the Presence of God." We may look at the traditional introductory lecture which he delivered to his new physics students for a particularly direct expression of his devotion in science. He felt that scientific discovery brought the human mind closest to the Divine, saying (Thompson, 1910:246), "We feel that the power of investigating the laws established by the Creator for maintaining the harmony and permanence of His works is the noblest privilege which He has granted to our intellectual state." He would conclude the lecture with the statement (Thompson, 1910:250),

> . . . we must remember that as the depth of our insight into the wonderful works of God increases, the stronger are our feelings of awe and veneration in contemplating them and in endeavouring to approach their Author. . . . By such feelings the earnest student of philosophy must always be impressed; so will he by his studies and successive acquirements be led 'through nature up to nature's God.'

It seems to have been in such terms that he viewed the Fourier equations, and his developed statement of what has now come to be called the second law. This he gave in a long series of articles to the Royal Society of Edinburgh, running from 1851 to 1854. His statement of the "dissipation of energy" which we saw in the last chapter came in 1852, the same year in which Thompson relates that he married Margret Crum, his childhood sweetheart, and resigned his Cambridge Fellowship (which he had maintained while teaching at Glasgow) (1908:9).

We are going to look at a summary reminiscence of Kelvin's concerning his own interpretation of the second law. However, a short groundwork must be set out on his view of the probable nature of the atom, for he comments on atoms in the same passage. Dampier (1949: 295ff), speaking of nineteenth-century science, has related that "hardness" and "persistence in time", qualities perceived in matter and ascribed to atoms, "strengthened immensely the common-sense view that matter was an ultimate reality." Kelvin supported the atomic theory, but found it philosophically more agreeable to "dematerialize" the atom, thus rendering it more tractable to creation. He attempted this from the theoretical standpoint, suggesting a "vortex-atom" concept in light of which the atom was seen to be a vortex-ring, rotating within and made up of a perfect, non-material fluid, the ether. Creation involved setting the vortexes in motion. (This theory was later to inspire Kelvin's colleague, Peter G. Tait to his own devout theory of matter, which we shall see in the next chapter.) With respect to both the second law and the vortex-atom theory, Thompson (1910:1091) comments:

> Again and again, in his public career, from his inaugural lecture of 1846 to the end [of] his life, Lord Kelvin declared his belief in Creative Power, and in an overruling Providence. In two points at least his scientific studies brought him to what he considered a direct demonstration of a definite creation: namely, the Fourier equations for the flow of heat, with the mathematical inference . . . that there must have been a beginning; and the vortex-atom conception, according to which the permanence of the atom proves that no known animate or inanimate physical agency could have originated them.

Thompson (1910:111) relates Kelvin's own views on these ideas, as he expressed them in a personal conversation in 1906. Kelvin was in a "chatty" mood, and Thompson had asked him point blank how he had missed being Senior Wrangler. Kelvin replied that Parkinson (who had won over him) ". . . had won principally on the exercises of the first two days, which were devoted to text-book work rather than to problems requiring analytical investigation." Kelvin continued, saying:

> 'I could have walked over the paper. A very good man Parkinson--I didn't know him personally at the time--who had devoted himself to learning how to answer well in examinations, while I had had, during previous months, my head in some other subjects not much examined upon--theory of heat, flow of heat between isothermal surfaces, dependence of flow on previous state, and all the things I was learning from Fourier.' Then he went on to explain how he had had his head in these problems before coming to Cambridge, and told me he wished he could find his note-book of the Senior Greek lectures of his last year at Glasgow, when he was supposed to be listening to Lushington on the Hippolytus of Euripides, for the notes would show that he was all the while working at his ideas on the uniform motion of heat, and on the Boscovichian idea of force acting independently of intervening matter. Then he drifted back to his own early writings on Fourier, and pulling from the shelf a copy of his Mathematical and Physical Papers, vol. i., pointed to page 15, where he gave the mathematical inference, as the result of assigning negative values to the time t, that there must have been a creation. 'It was,' he continued, 'this argument from Fourier that made me think there must have been a beginning. All mathematical continuity points to the necessity of a beginning--this is why I stick to atoms . . . and they must have been small--smallness is a necessity of the complexity. They may have all been created as they were, complexity and all, as they are now. But we know they have a past. Trace back the past, and one comes to a beginning--to a time zero, beyond which the values are impossible. It's all in Fourier.'

Kelvin's Overall Scientific-Religious Outlook

It is clear from Kelvin's comments that he viewed the second law as an argument for Creation. His positions on other scientific topics reveal further facets of his essentially religious outlook. At every turn he fought what he considered to be materialism, and advanced instead ideas consistent with the orthodox Christian position.[3]

Kelvin waged his fight with the evolutionary theory (that life had developed from matter without the intervention of creative design) throughout his own life. In denying that life had evolved on Earth, he was driven to suggest that it had been borne to earth by meteoric stones from a period of earlier creation. This idea provoked a number of critics. Thompson relates (1910:1103):

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[3]Agnes G. King (1925:28ff), Kelvin's niece, has given the following sketch of Kelvin in this regard:

> All through life Lord Kelvin retained a wonderful simplicity of character, which endeared him to every one. He had a simple, childlike faith which pervaded his whole being. The deeper he delved into Science and the more he studied its mysteries, the greater his veneration for the Maker of all.
>
> 'We must pause,' he said, 'face to face with the mystery and miracle of creation . . . the relations of matter and life are infinitely too complex for the human mind to understand. . . . The opening of a bud, the growth of a leaf, the astonishing development of beauty in a flower involve physical operations far beyond our comprehension. . . . A tree contains more mystery of creative power than the sun, from which all its mechanical energy is borrowed. An earth without life, a sun, and countless stars, contain less wonder than that sprig of mignonette. . . . Let us not imagine that any hocus-pocus of electricity or viscous fluid will make a living cell.' Again he said: 'If you think strongly enough, you will be forced by Science to a belief in God, which is the foundation of all religion.'
>
> 'In the evening mother read aloud Darwin's confession of faith, or rather his confession of want of faith. Uncle William [Kelvin] said of his views about the absence of evidence of design, that he considered such views utterly unscientific. He expressed himself very vehemently on the subject, and said that our own power of discussing and speculating about Atheism and Materialism was enough of itself to disprove such a theory. With regard to Evolution, he said that it could not in the least degree explain the great mystery of nature and creation: if all things originated in a single germ, then that germ contained in it all the marvels of creation, physical, intellectual and spiritual to be afterwards developed. It is absolutely impossible that atoms of dead matter should come together so as to make life.'
>
> His work was to him a kind of worship. His close study of the phenomena of nature and his constant discovery of new marvels seemed to bring him nearer and nearer to God, and he could never understand any one treating Science with any other feeling than reverence.

His own suggestion in 1871 of a possible introduction of life to this globe by meteoric sources, was often misunderstood or mis-stated. To a correspondent who wrote to him on this topic he replied in 1886:--

The "star germ theory" which I put forward as a possibility does not in the slightest degree involve or suggest the origination of life without creative power, and is not in any degree antagonistic to, or out of harmony with, Christian belief.

To another correspondent, in March 1887, he wrote:--

I think you will find nothing contrary to the Bible in the suggestion that some of the life at present on the earth may have come from seeds sown by meteoric stones. I have never thrown it out as more than a hypothesis that even so much was the case. But even if some of the living things on the earth did originate in that way so far as the earth is concerned, the origin of the species elsewhere in the universe cannot have come about through the functions of dead matter; and to our merely scientific judgment the origin of life anywhere in the universe seems absolutely to imply creative power. I believe that the more thoroughly science is studied the further does it take us from anything comparable to atheism.

In 1903 a letter of Kelvin's appeared in the London Times, respecting a lecture by one Professor Henslow. Thompson (1910:1098) gave a copy, "as corrected by Lord Kelvin's own hand." The letter reads in part:

I do not say that, with regard to the origin of life, science neither affirms nor denies creative power. Science positively affirms creative power. Science makes every one feel a miracle in himself. It is not in dead matter that we live and move and have our being, but in the creating and directive Power which science compels us to accept as an article of belief . . . We only know God in his works, but we are absolutely forced by science to admit and to believe with absolute confidence in a Directive Power. . . .

Clearly Kelvin's scientific concepts were compassed and focused by his religious belief. Further, he definitely held to the ancient dichotomy, inherent in Newton's ideas, between "dead matter" impotent in itself, and the creative, ordering power of the Divinity. Life was an example; it was a creative miracle, partaking of the divine spark. These ideas are written into his concept of the second law. Thompson relates (1910: 1093):

> He regarded life, however certainly its operations were governed by chemical and dynamical laws, as essentially outside the range of physics. He utterly repudiated all idea of the generation of living matter by force or motion of dead matter alone. "That life proceeds from life, and from nothing but life," was for him "true through all space and through all time." He declared that whereas the fortuitous concourse of atoms was the sole philosophic foundation for the second law of thermodynamics, the fortuitous concourse of atoms was powerless to account for the directed operations of living matter. "The influence of animal or vegetable life on matter is," he declared, "infinitely beyond the range of any scientific inquiry hitherto entered on. Its power of directing the motions of moving particles, in the demonstrated daily miracle of our human free-will, and in the growth of generation after generation of plants from a single seed, are infinitely different from any possible result of the fortuitous concourse of atoms."

The Grand Synthesis

It was Kelvin's ambition (as it was Einstein's later) to construct the comprehensive theory of the universe -- correct in all the proper mathematical and physical corners. After fifty years at it, during his jubilee celebration in Glasgow (attended by over 2,000 friends, professional colleagues, Lords, commoners and family) he announced his "failure" at the task. Throughout his life he had tried to unite the character and the modes of interaction of physical phenomena in a single, logical pattern. The culmination? "'I know,' he said on the day of his jubilee, 'no more of electric and magnetic force, or of the relation between ether, electricity, and ponderable matter, or of chemical affinity, than I knew and tried to teach to my students in my first lesson'" (Thompson, 1908: 23). To a friend he wrote, "I am as firmly convinced as ever of the absolute truth of the kinetic theory of gases. What I feel that I have failed in has been my persevering efforts during 50 years to understand something more of the luminiferous ether and of the manner in which it is concerned in electric and magnetic forces. . ." (Thompson, 1910:1013). But if a unified theory escaped him, there were solid advances. The vortex atom theory he had to abandon, and the discovery of radioactivity at the turn of the century was to confound all his prior assumptions with regard to the age of the earth and the possibility of material evolution; yet his synthesis of mechanics and heat flows stood firm.

In 1860, speaking before the Royal Society, he had expressed the sentiment that ". . . experiment within these walls must lead to a stage of knowledge in which the laws of inorganic nature will be known in this sense -- <u>that one will be known as essentially connected with all, and in which unity of plan, through an inexhaustibly varied execution, will be recognized as a universally manifested result of creative wisdom</u>" (Thompson, 1910:1092, emphasis added). This was his deepest hope, his great synthesis of science and religion; and in the second law he found at least partial fulfillment of that hope. At every turn it seemed capable of scientific amplification. Further, to many it "seemed to be restating the Biblical story of the creation in modern terminology" (Crowther, 1936:231). If one is to consider the more religious side of Newton's thought, Kelvin appears to have become the Newton of the molecular theory.

The import of his statement of the second law has come down to us virtually unchanged. Hugh D. Young, for example, in his introductory text, <u>Fundamentals of Mechanics and Heat</u> (1964:546) says:

> Generalizing, we make the following statement: It is impossible to construct a heat engine which operates in a cyclical process and which has no other effect than to take heat from a reservoir at one temperature and do an equivalent amount of mechanical work, without discarding <u>any</u> heat at a lower temperature. This generalization [was] first stated by Kelvin . . .

Modern technology conforms to and rests upon this principle; further, our cosmology has been for over a hundred years set in its mold. This is influence indeed. Whether the second law turns out to be correct or incorrect, or better said, complete or incomplete as a cosmological principle, it remains a very large intellectual achievement.

CHAPTER V

USES AND ABUSES FOR THE SECOND LAW: KELVIN, TAIT, CLIFFORD, MAXWELL AND TYNDALL

Kelvin stated the second law in England; it was accepted in most quarters with enthusiasm. A number of elements contributed to its success, not the least of these being Kelvin's own talent and prestige. Another element, undoubtedly a large one, was the fact that the law presented the immediate prospect of increases in technological efficiency at a time when Britain was undergoing industrial transformation.[1] No matter that the law imposed severe restrictions on ultimate efficiency; no matter that it held the world was dissipative in nature; its first import was one of physical progress and increased prosperity.

Another element was the religious temper of the time. The second law appeared devout, and it attracted the support of the devout. Support was important. The scientific movement in England was an infant promising to become expensive, yet it had the sparest funding. As P. G. Tait commented (Nature, July 15, 1875:201), "The true votary of science, in this country at least, rarely meets with encouragement and support. Mole-eyed State!" Private bequests by wealthy individuals were the largest single source of funds for scientific studies in the universities

[1]The steam engines, generators, etc. then in use had grown largely from innovative practical engineering without benefit of developed thermodynamic theory, and their efficiencies were lower than the law predicted to be possible.

and colleges (Sanderson, 1972:78ff). The universities, and usually the individuals making donations, professed the orthodox devotion. And as Lord Derby commented in his address "On the Endowment of Scientific Research," (Nature, December 23, 1875:141): "Respect the founder's object . . . if you do not, you will have no new endowments." The Bridgewater Treatises (1836) were a product of science within this social milieu. Written by distinguished scientists appointed by the Royal Society, the treatises had been funded through a bequest of Lord Bridgewater. He instructed that they should be dedicated both in word and substance to the "power, wisdom, and Goodness of God," and he left a lot of money for the purpose. Simply, orthodoxy in science aided funding; what Kelvin called "cheap materialism" didn't.

The 1871 meeting of the British Association for the Advancement of Science offers a curious commingling of three themes; need for funding and support, desire to avoid the charges of heresy, and invocation of the second law to show that science was orthodox. Kelvin had been elected president of the association; his inaugural address put forward the theme that "Experimental science ought to be made with us an object of national concern" (Nature, August 3, 1871:262ff). The address explored many avenues to this goal, and wound up on the note that "Overwhelmingly strong proofs of intelligent and benevolent design lie all around us, teaching us that all living beings depend on one ever-acting Creator and Ruler."

Peter G. Tait, Kelvin's close friend and colleague at Glasgow University, had been elected president of the mathematical and physical science section of the Association. In his address, which followed Kelvin's, he expressed concern for ". . . what has been so often and so persistently croaked against the British Association, viz. that it tends to develop what are called scientific heresies" (Nature, August 3, 1871: 270ff). Tait continued:

> It seems to me, that the proper answer to all such charges will be very simply and easily given if we merely show that in our reasonings we invariably confine our physical conclusions strictly to matter and energy (things which we can weigh and measure). Whatever is neither matter nor energy . . . is not a subject to be discussed, even by implication . . . Ordinary dead matter, [he said] is strictly and exclusively in the domain of physical science. [Then;] A profound lesson may be learned from one of the earliest papers of our President [Kelvin], published when he was an undergraduate at Cambridge, where he shows that Fourier's magnificent treatment of the conduction of heat . . . when extended to time past . . . indicates a state of things which could not have resulted under known laws from any previous distribution. The example is now adduced, not for its bearing on heat alone, but as a simple illustration of the fact that all portions of our science, and especially that beautiful one the Dissipation of Energy, point unanimously to a beginning.

Tait had been moved to his comments by public debates of that period, as to whether evolution, conservation of energy, and other theories were not heretical.[2] It would seem that social pressures helped determine the theoretical posture of English science during this period. Helmholtz, on the continent, commented that English scientists ". . . dared not propigate their views openly, for fear of compromising their social interests" (Nature, August 10, 1871:288).

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[2]With the exception of evolution, the main charges of heresy appeared to be directed squarely at physics. Dampier (1949:305) comments, "The principles of the conservation of matter and energy, combined with atomic theory, were used as the chief basis of materialism." In an article in the London Quarterly Review, John Moore charged that the Doctrine of Evolution and the Conservation of Energy were both Heretical Dogmas. This sparked a reply by Charles Brook in Nature, June 13, 1872, pp. 122-125. Moore came back with further comment, which was printed in the July 4, 1872, issue of Nature, pp. 180-181. Both writers allude to other comments in the popular literature regarding science and "heresy."

However, compromise seemed to be needed. Orthodoxy insisted on God's continuing presence in the scientific outlook. On the other hand, a too enthusiastic orthodoxy was a damper. Scientific progress demanded the discovery and extension of laws pertaining in their pragmatic effects to matter. Miraculous action by the Deity, hinted to be just around the corner in Newton's work, had to be pushed out of the laboratory.[3] To the devout but empirical scientist, 'God at a distance' was the thing needed. That, Kelvin's second law exactly provided. Really, it was a brilliant compromise, combining powerful arguments for God's past action which could satisfy orthodoxy, while assuring that He would not likely pop up to confound the empiricist in the lab next morning. Of this period in England, Dampier has commented (1949:311), "If there was still need of a Creator, it seemed likely that He had turned away and left the great machine to spin unheeded down the ringing grooves of change." The second law was the quintessential distillate of that outlook.

Kelvin's Personal Influence As An Element in the Success of the Second Law

It is given to only a handful of men to become a social force in their own time; Kelvin became one in England. Andrew Gray, student, friend, and later colleague of Kelvin's at Glasgow, has spoken of "the inspiration which his work and example gave to others." He said, "There was no one, however eminent, who was not proud to acknowledge his obligations to his genius" (1973:305). Intense veneration developed for Kelvin in his home country during the latter half of his life. He seemed a man

[3]Kelvin himself did some gentle pushing with the comment, "If a probable solution, consistent with the ordinary course of nature, can be found, we must not invoke an abnormal act of creative power" (Thompson, 1910:1091).

for all scientific seasons, being teacher, theoretical innovator, practical inventor (over 40 patents), energetic leader of the British Association for the advancement of science, advisor of public companies and Royal commissions, arbiter of scientific disputes, most awarded British scientist of his time, champion of the movement to make science a national priority, member of the Royal Society, and on top of all this -- defender of the faith. He became "Mr. Science" to almost three generations of Britishers. Kelvin's role as an historical figure goes far beyond his scientific contributions. In England, during the most crucial period of industrial transformation, he was a key figure in making science *itself* happen. English history would not be the same without him.

In person, particularly in debate, Kelvin was something of an intellectual battering ram. Possessing strong convictions, charming, intensely energetic and owning a command over higher mathematics that few other men had, he was virtually irresistible wherever mathematics counted. He tended to put every proposition into mathematical form; from that point he almost always had the advantage. Gray (1973:309) reflects that "he was no mere mathematician, but a man who, like the prophets of old, could divine what is hid from the eyes of ordinary mortals."

Thompson (1910:1123) reprints a letter from one of Kelvin's students:

> In my time nothing was more characteristic of Sir William than the thoroughness with which he thrashed out every subject that he took up. His students were quite persuaded that he knew everything about a subject that could be known, and they felt that he was perfectly justified in his sometimes rather unsparing language about charlatins, "showmen," mere brilliant experimenters who wished to pose as philosophers. In fact, our faith in him went so far that I have heard some of the best students say that they were hardly satisfied with any philosophical theory till it had Sir William's *imprimatur*, and were almost content to accept it as all right if it got that.

Kelvin, in short, could sell a viewpoint -- and he was selling the second law.

Kelvin's Use of the Second Law Against Evolutionary Theory

Kelvin utilized the second law to discredit uniformitarian geology, and through it, evolution. Evolution required great stretches of time to be tenable. Uniformitarian geology provided that time; Kelvin denied it. His friend and associate Tait joined him. In Darwin's Century (1961:234ff), Loren C. Eiseley comments, "The attack (on Darwin via geological theory) had been launched by Lord Kelvin, considered by many historians of science to be the outstanding physicist of the nineteenth century. Whether Lord Kelvin and his Scottish associate, Peter Tait, saw the inevitable consequence of their thought one cannot but wonder, since they were devoutly religious men. At any rate, they pressed their advantage hard. . ." In 1865 Kelvin published a paper entitled "The Doctrine of Uniformity in Geology Briefly Refuted." In 1868 "On Geological Time" appeared. In it Kelvin commented (Vol. II, 1894:11ff): "A great reform in geological speculation seems now to have become necessary." He went on to give the view of Playfair and Hutton: "We discover no mark either of the commencement or the termination of the present order."

"Nothing," said Kelvin, "could possibly be further from the truth than that statement." He argued, basically, that both the sun and the earth were cooling, and in terms of the sources of energy known to exist for each, the rate of cooling given by the Fourier equations indicated that they had had a relatively brief past history, and would have a similarly brief future. Evolution needed several billions of years; Kelvin offered mere millions. Most physicists fell in with him. Darwin called Kelvin an "Odious spectre"; elsewhere he commented, "I am greatly troubled at the short duration of the world according to Sir W. Thomson for I require for my theoretical views a very long period . . ." (Eiseley, 1961: 235). "Kelvin," comments Eiseley, "pressed his advantage relentlessly. 'We find at every turn something to show . . . the utter futility of (Darwin's) philosophy,' he said in 1873." The debate over this issue separated many physicists, geologists and biologists into two antagonistic camps lasting to the end of the century, when the discovery of radioactivity and nuclear energy decided the issue against the physicists. Eiseley comments (1961:234), ". . . in this long controversy extending well over half a century, the physicists made extended use of mathematical techniques and still were hopelessly and, it must be added, arrogantly wrong."

Mathematics alone does not make a science. Other elements are involved, among them the exercise of speculative reason (Whitehead, 1962: 38), coupled with a 'feel for the go of things' in qualitative as well as quantitative terms. Had Kelvin not been consistently antagonistic to the broader implications of geological and evolutionary theory, he might have utilized them in conjunction with his own calculations -- correct in themselves -- to suggest the presence of an "X" factor in the picture; an unknown source of further energy. How close he came to such a presentiment may be estimated from his comment in 1861: "We may say with . . . certainty that the inhabitants of the earth cannot continue to enjoy the light and heat essential to their life for many million years longer, unless new sources now unknown to us are prepared in the great storehouse of Creation" (Eiseley, 1961:238).

John Tyndall and Evolutionary Theory

While Kelvin and many other physicists denied evolution, John Tyndall welcomed it. Tyndall, a distinguished fellow physicist and contemporary of Kelvin's who had studied in Germany and become an adherent of materialism there, was elected president of the British Association in 1874. His inaugural address, delivered in Ulster Hall before some 1,800 gathered scientists, dignitaries and interested laymen (and carried by telegraph to the major newspapers), was a frank advocacy of evolution -- and materialism. Presented with a force and brilliance altogether equal to Huxley's, it immediately became famous (or scandalous, depending on one's outlook).

In his address (Nature, August 20, 1874:312ff), Tyndall built from the foundation of Democritean atomism, saying, "What these atoms, self-moved and self-posited, can and cannot accomplish in relation to life, is at the present moment the subject of profound scientific thought." "The science of ancient Greece," he continued, "cleared the world of the fantastic images of divinities operating capriciously through natural phenomena. What then, stopped its victorious advance? Christians," he said.

> The sufferings of the early Christians, and the extraordinary exhaltation of mind which enabled them to triumph over the diabolical tortures to which they were subjected, must have left traces not easily effaced. They scorned the earth, in view of that 'building of God, that house not made with hands, eternal in the heavens.' The Scriptures which ministered to their spiritual needs were also the measure of their science.

Tyndall continued, tracing the slow re-emergence of science into the mid-nineteenth century. This progress, he felt, had brought scientists to a watershed. Was science to remain within, or break free of the mold supplied by religious orthodoxy? "Two courses, [stated Tyndall] and two only are possible."

> Either let us open our doors freely to the conception of Creative acts, or, abandoning them, let us radically change our notions of matter . . . Taught as we have been to regard . . . [our previous] definitions of matter as complete, we naturally and rightly reject the monstrous notion that out of such matter any form of life could possible arise. But are the definitions complete? Everything depends on the answer to be given to this question. Trace the line of life backward, and see it approaching more and more to what we call the purely physical condition . . . Can we pause here? . . . Is there not a temptation to close to some extent with Lucretius, when he affirms the "Nature is seen to do all things spontaneously of herself without the meddling of the Gods?" Or with Bruno, when he declares that matter is not "that mere empty capacity which philosophers have pictured her to be, but the universal mother who brings forth all things as the fruit of her womb?" . . . Abandoning all disguise, the confession that I feel bound to make before you is that I prolong the vision backward across the boundary of the experimental evidence, and discern in that matter, which we in our ignorance, and notwithstanding our professed reverence for its Creator, have hitherto covered with opprobrium, the promise and potency of every form and quality of life (Nature, August 20, 1874:317ff).

Tyndall's address evoked a storm of public protest. He afterward commented (Vol. II, 1902:215):

> The world has been frequently informed of late that I have raised up against myself a host of enemies: and considering, with few exceptions, the deliverances of the Press, and more particularly the religious Press, I am forced to admit that the statement is only too true. . . .
>
> From fair and manly argument, from the tenderest and holiest sympathy on the part of those who desire my eternal good, I pass by many gradiations, through deliberate unfairness, to a spirit of bitterness, which desires with a fervor inexpressible in words my eternal ill.

Kelvin, reported Thompson, quietly wrote to a friend that Tyndall's address had been "particularly inappropriate."

Yet Tyndall had put his finger on the heart of the matter. It is not too much to say he found the lynch-pin upon which evolution, the second law, and other scientific theories of the time turned in their interpretation. Was "Nature, free at once, and rid of her haughty Lords . . . seen to do all things spontaneously of herself, without the meddling of the Gods?" (Nature, August 20, 1874:310). --Or was she, as tradition taught, passive, brute matter, potter's clay, incapable of producing structure, order, life -- in Newton's words -- "without ye mediation of something else wch is not material?" (Turnbull, Vol. III, 1961:253). If the former, then life, order, and the ongoingness of things are most likely the product of a self-sufficient, self-sustaining Nature. If the latter, we must look to "Creation" as the ultimate source of these things.

It would appear that most of the biologists got over the watershed; Kelvin kept himself, and physics, on the side of tradition. The separation appears to have remained to the present day. In its clearest form, it has been expressed by the Russian biologist A. I. Oparin, who writes within the framework of dialectical materialism. Oparin (Moscow, 1960:17) comments that the second law

> . . . expresses the statistical tendency of nature to disorder, to leveling . . . [to] an increase of entropy . . . In contradistinction to this, in organisms not only does there not occur an increase in entropy, but there is even the possibility of its decrease. Thus, it is as though one had gathered that the basic law of physics is the tendency to disorder, to an increase of entropy, but the basic law of biology, on the contrary, is the growth of orderliness -- a decrease in entropy.

P. G. Kuznetsov (in Trincher, Biology and Information, Moscow, 1964; New York, 1965:87ff) likewise holds that life as an entirety "contradicts the Carnot principle in its ordinary formulation." He goes on to criticize the principle of Kelvin and Clausius, saying that the second law ". . . corresponded to a profound human sentiment, with the ideal anthromorphic representation of nature."[4]

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[4]It is interesting to compare the above views, given by modern Russian scientists, with those given by W. P. Allis and M. A. Herlin, physicists at M.I.T. (1952:93):

Returning to Tyndall, we find that his view of the physical universe contained no hint of the second law as an overarching principle; indeed, the second law was conspicuously absent. Concerning the universe he held that

> The parts of the 'stupendous whole' shift and change, augment and diminish, appear and disappear, while the total of which they are a part remains quantitatively immutable. Immutable, because when change occurs it is always polar -- plus accompanies minus, gain accompanies loss, no item varying in the slightest degree without an absolutely equal change of some other item in the opposite direction. Has this uniformity of nature ever been broken? The reply is: 'Not to the knowledge of science' (Vol. II, 1902:358ff).

> The celebrated Robert Boyle regarded the universe as a machine; Mr. Carlyle prefers regarding it as a tree . . . A machine may be defined as an organism with life and direction outside; a tree may be defined as an organism with life and direction within. In light of these definitions, I close with the conception of Carlyle. The order and energy of the universe I hold to be inherent, the expression of fixed law and not of arbitrary will, exercised by what Carlyle would call an Almighty Clockmaker (Vol. II, 1902:354).

The Unseen Universe of Tait and Stewart

If Tyndall propounded materialism and ignored the second law, Peter G. Tait and Balfour Stewart took the opposite tack, outdoing even Tait's colleague and friend Kelvin in professed religious devotion, and advocacy of the second law. Tait had referred to Kelvin's principle of dissipation as "beautiful." He and Stewart went on to make it the key

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> Even the simplest living organism is very highly organized, which means that its entropy is abnormally low. At death, rapid irreversible changes take place and the entropy rises to a more normal value. Are the forces which maintain this low entropy violating the second law? If life could continue in an 'isolated' body, they would be, but it cannot. 'Life' needs 'dead' surroundings, and produces order within itself only at the expense of disorder in its environment, in complete accordance with the Clausius inequality . . . The irreversibility of life is a good indication that the disorder it produces in its surroundings is always far greater than the order produced within itself.

--A profound difference in both philosophy and empiric orientation lies between the above views; a difference, moreover, unresolved.

concept of a treatise in cosmology wherein, "Science . . . instead of appearing antagonistic to the claims of Christianity, is in reality its most efficient supporter" (Stewart and Tait, 1890:271). The book, titled The Unseen Universe and first published anonymously,[5] ". . . created a great sensation" (Knott, 1911:237). It went through three subsequent editions and twelve printings, provoking comment from both the devout and the otherwise inclined. The authors held that "As a matter of universal scientific experience . . . the visible universe is <u>not</u> eternal, and has <u>not</u> the power of originating life" (Stewart and Tait, 1890:245). Argument against the eternity of the world centered around Kelvin's dissipation principle. They inferred from it that, "We have . . . reached the beginning as well as the end of the present visible universe, and have come to the conclusion that it began in time and will in time come to an end" (Stewart and Tait, 1890:128). The authors reflected upon how this conclusion affected the materialistic position. They said (1890: 92-93):

> Let us next briefly allude to the position of the extreme school of science. Ignoring all but the visible universe, and applying the principle of Continuity /conservation/ to its phenomena, the members of this school were indubitably led to most important generalisations regarding the method of working of that great system. So far the Genius whom they had summoned up appeared to be the very principle of order. But things wore a different complexion as time went on. It was fancied that historical Christianity must disappear, and that the belief in the reality of a future state must follow after it. They were surrendered. But it was extremely startling when the Genius invoked, not content with what he had already devoured, broadly hinted that the whole visible universe would furnish an acceptable sacrifice, -- <u>then</u> even the most extreme partisans of the school began at length to be alarmed. It was too much to be borne, that a Genius summoned up in the very name of order should turn out to be a demon so

[5]Some thought the book had been authored by Kelvin. Thompson has related that Kelvin disliked the book, but did not trouble himself to deny authorship.

> insatiate as this: Must the whole visible universe, indeed, arrive at such a state as to be totally unfit for the habitation of living beings? The individual they were content to sacrifice, perhaps even the race, but they would spare the universe. Undoubtedly, if it be possible to pity men who could so easily dispense with Christianity and immortality, they had at length got themselves into a deplorable dilemma. For the principle they had invoked was absolutely without pity, and in the most heartless manner continued to point towards the sacrifice of the visible universe. This, they were told, was only a huge fire, and must ultimately burn itself out. Nothing would be left but the ashes, -- the dead and worthless body of the present system.

Stewart and Tait used the second law as a weapon against materialism. They went further. Not content with the future prediction of the second law, they went on to derail conservation as a material principle, saying (1890:157), "We may now perhaps imagine, that as a separate existence itself the visible universe will ultimately disappear. . . ."

How was this accomplished from the standpoint of physical theory? Recollect (Chapter IV) that Kelvin had advanced the vortex-atom idea, whereby material atoms were no more than vortexes set spinning in a perfect or frictionless fluid, the ether. Tait, who had been experimenting with metal discs spun in vacuum, noticed that the discs heated up. He thought that he had found the ether-drag, or ether friction, posited by Whewell. (Actually, his vacuum had not been all that good; he was getting air resistance). However, he utilized his findings to modify Kelvin's vortex theory. In Tait's view, Kelvin's vortex atoms were spinning in an <u>imperfect</u> fluid, and thus would eventually die out. Conservation (or as they called it, continuity) became metaphysical, applying to the nonmaterial or "invisible universe". Stewart and Tait stated (1890:156-7):

> We cannot, in fact, if we agree to hold at the same time the principle of unbroken continuity and the vortex-ring theory of formation of the visible universe, regard the material whose rotating parts are ordinary matter as an absolutely perfect fluid. . . . But if the visible universe be developed from a material which is not a perfect fluid, then the argument deduced by Sir W. Thomson

> in favour of the eternity of ordinary matter[6] disappears, since this eternity depends upon the perfect fluidity of that out of which it was developed. In fine, if we suppose the material universe to be composed of a series of vortex-rings developed from something which is not a perfect fluid, it will be ephemeral, just as the smoke-ring which we develop from air, or that which we develop from water, is ephemeral, the only difference being in duration, these lasting only for a few seconds, and the others it may be for billions of years.

The authors continued (1890:194):

> Indeed we can hardly escape from the conclusion that the visible universe must in matter, as well as in transformable energy, come to an end. But the principle of Continuity upon which all such arguments are based still demanding a continuance of the universe, we are forced to believe that there is something beyond that which is visible, or that, to use the words of an old writer (which we have inscribed on our title-page), -- 'the things which are seen are temporal, but the things which are not seen are eternal.'

In their final chapter, the authors speculated on whether evil was eternal and whether it would survive the dissolution of this material universe. They concluded on scriptural authority that "We are drawn, if not forced, to surmise that the dark thread known as evil is one which is very deeply woven into that garment of God which is called the Universe . . . we are led to surmise that evil is eternal, and therefore we cannot easily imagine the Universe without its Ghenna, where the worm dieth not, and the fire is not quenched" (1890:268).

William K. Clifford's Reaction

William K. Clifford, a professor of mathematics and mechanics at University College, London, and a Fellow of Trinity College, Cambridge, (who was a personal friend of Tait's) commented in the Fortnightly Review (Clifford, Vol. I, 1901:268ff):

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[6]Kelvin used the vortex atom theory to argue for creation, not the eternity of matter. Others used the "perfection" of the atom as an argument for its eternity.

> This sleepless vengance of fire upon them that have not seen and have not believed, what has it to do with the gentle patience of the investigator . . . that will ask only consideration and not belief. . .?
>
> That which you keep in your hearts, my brothers, is the slender remnant of a system which has made its red mark on history, and still lives to threaten mankind. The grotesque forms of its intellectual belief have survived the discredit of its moral teaching . . . Take heed lest you have given soil and shelter to the seed of that awful plague which has destroyed two civilisations, and but barely failed to slay such promise of good as is now struggling to live among men.

Clifford, religious in his youth, had by the time of that comment become an agnostic. Other reactions to The Unseen Universe were diverse. Knott, Tait's biographer relates (1911:239):

> Truly the reviews and critiques of The Unseen Universe were as varied as the religious and irreligious views of the critics who wrote them. To one it was a "masterly treatise," to another it was full of "the most hardened and impenitent nonsense that ever called itself original speculation." . . . One critic there was, the versatile and brilliant Clifford, who knowing these truths in all their purely physical significance, gave the authors a terrible trouncing.

Clifford's views on the second law were given in his essay "First and Last Catastrophy" (Vol. I, 1901:222ff), initially delivered before the Sunday Lecture Society in London, 1874. "I propose in this lecture," he said, "to consider speculations of quite recent days about the beginning and the end of the world." He went forward into a detailed examination of what he felt the Fourier equations (which were at the heart of Kelvin's theory) implied and did not imply. His argument makes a lengthy quotation, but it is one of the most lucid criticisms of the cosmological application of the second law that has been given, striking not at the Fourier equations, but the manner of their use. Clifford said:

> A remark was made about thirty years ago by Sir William Thomson upon the nature of certain problems in the conduction of heat. These problems had been solved by Fourier many years before in a beautiful treatise. The theory was that if you knew the degree of warmth of a body, then you could find what would happen to it afterwards; you would find how the body would gradually cool.

> Suppose you put the end of a poker in the fire and make it red hot, that end is very much hotter than the other end; but if you take it out and let it cool, you will find that heat is travelling from the hot end to the cool end; and the amount of this travelling, and the temperature at either end of the poker, can be calculated with great accuracy. This comes out of Fourier's theory. Now suppose you try to go backwards in time, and take the poker at any instant when it is about half cool, and say: "Does this equation give me the means of finding out what was happening before this time, in so far as the present state of things has been produced by cooling?" You will find the equation will give you an account of the state of the poker before the time when it came into your hands, with great accuracy up to a certain point; but beyond that point it refuses to give you any more information, and it begins to talk nonsense. It is in the nature of a problem of the conduction of heat that it allows you to trace the forward history of it to any extent you like; but it will not allow you to trace the history of it backward beyond a certain point. . . .
>
> If we apply that same consideration to the case of the poker, and try to trace back its history, you will find that the point where the equation begins to talk nonsense is the point where you took it out of the fire. . . .
>
> /Yet, he said/ Upon this remark of Sir William Thomson's /concerning the Fourier equations/. . . a most singular doctrine has been founded . . . your speculator comes; he reads a sentence, and says: "Here is an opportunity for me to have my fling." And he has his fling, and makes a purely baseless theory about the necessary origin of the present order of nature at some definite point of time which might be calculated. But, if we consider the matter, we shall see that this is not in any way a consequence of the theory of the conduction of heat; because the conduction of heat is not the only process that goes on in the universe.

According to Clifford, then, the cosmological model of the second law was essentially a speculation, constructed from concepts which, in themselves, did not necessarily lead in that direction.

Returning for a moment to The Unseen Universe of Stewart and Tait, it may be said that their particular arguments for the Creation, and ultimate dematerialization of the physical world have long since passed into oblivion. However, the direction of their thought has remained. Eddington, for example, gave a very "dematerializing" model of the universe when, in 1934, he said (1959:71):

> It has been widely supposed that the ultimate fate of protons and electrons is to annihilate one another, and release the energy of their constitution in the form of radiation. If so it would seem that the universe will finally become a ball of radiation, becoming more and more rarified . . . About every 1,500 million years this ball of radio waves will double its diameter; it will go on expanding in geometrical progression forever.

A future visitor to that universe would find little but a void. This theoretical position on the physical world, which seems to embrace the desire that it finally vanish, is also found in the cosmology of Pierre Teilhard de Chardin. In his Phenomenon of Man (1959:271ff) he recognizes ever-increasing entropy, and advances the idea that only the soul "escapes and is liberated from it. We come [he said] to escape from entropy by turning back to Omega: the hominisation of death itself." He continues: "Thus from the grains of thought forming the veritable and indistructable atoms of its stuff, the (spiritual) universe -- a well defined universe in the outcome -- goes on building itself above our heads in the inverse direction of matter which vanishes."

If such a world-prospect is comforting to the believer, it can produce an entirely different reaction in one who is not. Bertrand Russell, faced with the entropic model of the universe, and also adhering to the essentially materialist faith, penned, in 1923, "A Free Man's Worship" (1972:110ff):

> . . . That Man is the product of causes which had no prevision of the end they were achieving; that his origin, his growth, his hopes and fears, his loves and his beliefs, are but the outcome of accidental collocations of atoms; that no fire, no heroism, no intensity of thought and feeling, can preserve an individual life beyond the grave; that all the labor of the ages, all the devotion, all the inspiration, all the noonday brightness of human genius, are destined to extinction in the vast death of the solar system, and that the whole temple of Man's achievement must inevitably be buried beneath the debris of a universe in ruins -- all these things, if not quite beyond dispute, are yet so nearly certain, that no philosophy which rejects them can hope to stand. Only within the scaffolding of these truths, only on the firm foundation of unyielding despair, can the soul's habitation henceforth be safely built.

In the above words, Russell spoke the mood of others shortly after the turn of the century. Reflecting upon the growing certainty of the cosmological model of the second law, Eddington in 1927 said:

> The law that entropy always increases -- the second law of thermodynamics -- holds, I think, the supreme position among the laws of nature. If someone points out to you that your pet theory of the universe is in disagreement with Maxwell's equations--then so much the worse for Maxwell's equations. If it is found to be contradicted by observation -- well, these experimentalists do bungle things sometimes. But if your theory is found to be against the second law of thermodynamics I can give you no hope; there is nothing for it but to collapse in deepest humiliation.

By 1964 Jacques Barzun could comment (1964:117), "Modern physics . . . is no longer sure of the 'heat death' of the universe so popular with nineteenth-century scientists and so lowering to the spirits of their audiences. But . . . I have nowhere seen any acknowledgement that it was an historical calamity to have saddened, precisely with the 'heat death' story, the three generations of men spanned by the lives of Tennyson and Henry Adams. Mental suffering is a fact, as important sometimes as the physical. . . ."

James Clerk Maxwell

Maxwell was "fey" -- or so says Ronald Clark somewhere in his biography of Einstein. Gentle, poetic, he seemed able to touch the inside of things. He died at the age of 47, his work cut short in mid-career. As a young man of 22 he had written "Reflections from Various surfaces." A scrap from it reads (Cambell, 1882:593):

> Oft in yonder rocky dell
>   Neath the birches' shadow seated,
> I have watched the darksome well,
>   Where my stooping form, repeated,
>   Now advanced and now retreated
> With the spring's alternate swell,
>   Till destroyed before completed
> As the big drops grew and fell.

He walked a path closer to nature than man. Much of his thought portended what has been best in physics since; among other things it may be said that his equations on light, equations which Kelvin begrudged him, have stood unchanged by relativity and everything else.

He took a poet's rapture in nature, and an understanding of his feelings aids appreciation of his physical thought. His feelings caused him to depart -- and that, strongly -- from the tradition in English science around him. That tradition involved an intensely competitive training toward mastery of objective concepts, expressed if not contained in mathematical calculation and argued with polish through the upper stages of education. Kelvin, who tended to see mathematics as "the only true metaphysics;" who thrashed every concept into a mechanical form, mathematically expressed, was a wholehearted product of that tradition. Maxwell transcended it.

In the same year that Kelvin stated with mathematical virtuosity, his principle of dissipation, Maxwell wrote "A Vision of a Wrangler, of a University, of Pedantry, and of Philosophy." In it he relates being visited by a hag, embodying the physics taught him:

> Angular in form and feature,
> Unlike any earthly creature,
> She had properties to meet your
> Eye whatever you might view.
> Hair of pens and skin of paper;
> Breath, not breath but chemic vapour;
> Dress, --such dress as College Draper
> Fashions with precision due.
>
> The voice (he said) the spectre spoke in,
> Might be known by many a token
> To proceed from metal, broken
> When acoustic tricks were tried.

The hag proceeded to call down an unwanted blessing upon him:

"Powers!" she cried, with horse devotion,
"Give my son the clearest notion
How to compass sure promotion,
  And take care of Number One...
  ...Mathematics always pays.
Suddenly, (he said) my head inclining,
I beheld a light form shining;
And the withered beldam, whining,
  Saw the same and sunk away.

Of this shining light, he said:

I could never finish telling
You of her that has her dwelling
Where those springs of truth are welling,
  Whence all streams of beauty run.
She has taught me that creation
Bears the test of calculation
But that man forgets his station
  If he stops when that is done.

Is our algebra the measure
Of that unexhausted treasure
That affords the purest pleasure,
  Ever found when it is sought?
Let us rather, realizing
The conclusions thence arising
Nature more than symbols prizing,
  Learn to worship as we ought.

(from Campbell, 1882:612ff.)

Maxwell would submit to neither a mechanical or mathematical straightjacket; it is somewhat ironic that his equations on light quite went beyond Kelvin's appreciation (Gray, 1973:305; Thompson, 1910:1015ff.)

Like Kelvin, Maxwell was a deeply sincere Christian. However, where Kelvin's devotion was traditional and orthodox, Maxwell's was more theistic and optimistic; God and truth were present in nature. In his "Student's Evening Hymn," (1853, Campbell, 1882:595) he said:

Through the creatures Thou has made
  Show the brightness of Thy glory,
Be eternal Truth displayed
  In their substance transitory,
Till green Earth and Ocean hoary,
  Massy rock and tender blade
Tell the same unending story--
  We are Truth in form arrayed.

Maxwell did not care much for the second law, and a good bit of his thought on the subject went toward ways of transcending it. In a letter to Peter Tait in 1876 (Knott, 1911:222) he referred to the second law as an "indignity." In his review in Nature magazine of "Tait's Thermodynamics" (Niven, Vol. II, 1965:660ff) he commented of the second law, ". . . we have reason to believe that though true, its truth is not of the same order as that of the first law . . . the second law of thermodynamics is continually being violated, and that to a considerable extent, in any sufficiently small group of molecules belonging to a real body. . ." In order to take advantage of molecular fluctuations, he conceived of "small but lively intelligent beings," capable of sorting slow from fast molecules and thus restoring macroscopic temperature and pressure differences.

Kelvin nicknamed them "demons" and in a paper for Nature magazine (April 9, 1874:441ff.) entitled "Kinetic Theory of the Dissipation of Energy," he called up an army of them, all wielding cricket bats, to fight the advance of energy dissipation. In so doing, Kelvin anthropomorphized them, and then dismissed them. "If," he said, "no selective influence, such as that of the ideal "demon", guides individual molecules, the average result of their free motions and collisions must be to equalize the distribution of energy. . . ."

In an undated letter to Tait (Knott, 1911:214) Maxwell grumbled, "Concerning Demons. Who gave them this name? Thomson." He went on to suggest the demon as a valve. "As such," he said, "value him. Call him no more a demon but a valve like that of the hydraulic ram, suppose."

Maxwell's Demon has been batted around sporadically in physics literature ever since. Most treatments (see for example Bent, 1965:72ff., and Feynman, Vol. I, 1963:46-1ff) in one way or another dismiss him. But he refuses to quite go away. Bridgman (1969:5-6) has commented "Maxwell and his demon (were) met by the pious hope that for some inscrutable reason no demon would ever be able to crash the gate of our laboratories. But today, when it is so easy to conjure the capricious happenings of the atomic world up into the control of events on the scale of daily life. . . I believe that many physicists honestly do not know whether or not to think that a sufficiently ingenious combination of means now in our control might violate the second law on a commercially profitable scale."

Maxwell argued for Creation, but he argued his own way and ignored the second law in this respect. In a manner consistent with his poetic muse, he held that the unchangability and perfection of the atom indicated its creation at the hands of God. He argued this in his inaugural address as president of the British Association in 1873. Tyndall jumped him on that conclusion, in his own inaugural address the following year. The positions of the two men are pure cases; the theist arguing that the physical perfection of the world implies its creation, the materialist following as devil's advocate with the point that a "perfect" physical world needs, after all, no Creator. Maxwell had begun his argument with the Lucretian concept of the eternity of the atom (Niven, Vol. II, 1965:373ff.). He said:

In his dream of nature, as Tennyson tells us, he (Lucretius)

> "Saw the flaring atom-streams
> And torrents of her myriad universe,
> Ruining along the illimitable inane,
> Fly on to clash together again, and make
> Another and another frame of things
> For ever.

Against this Maxwell advanced his inference of Creation:

> No theory of evolution can be formed to account for the similarity of molecules, for evolution necessarily implies continuous change, and the molecule is incapable of growth or decay, of generation or destruction.
>
> None of the processes of Nature, since the time when Nature began, have produced the slightest difference in the properties of any molecule. We are therefore unable to ascribe either the existence of the molecules or the identity of their properties to the operation of any of the causes which we call natural.
>
> On the other hand, the exact equality of each molecule to all others of the same kind gives it, as Sir John Herschel has well said, the essential character of a manufactured article,[7] and precludes the idea of its being eternal and self-existent. . . . Science is arrested when she assures herself, on the one hand, that the molecule has been made, and on the other, that it has not been made by any of the processes we call natural. . . . We have reached the utmost limit of our thinking faculties when we have admitted that because matter cannot be eternal and self-existent it must have been created. . . . molecules . . . the foundation stones of the material universe -- remain unbroken and unworn.
>
> They continue this day as they were created -- perfect in number and measure and weight, and from the ineffaceable characters impressed on them we may learn that those aspirations after accuracy in measurement, truth in statement, and justice in action, which we reckon among our noblest attributes as men, are ours because they are essential constituents of the image of Him who in the beginning created, not only the heaven and the earth, but the materials of which heaven and earth consist.

"--I doubt," rejoined Tyndall in his own address, "the legitimacy of Maxwell's logic, but it is impossible not to feel the ethic glow with which his lecture concludes" (Nature, August 20, 1874:312).

Maxwell was incapable of defending himself with the "argument from perfection" which he had assumed. All he could do was write, in

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[7]C. J. Munro, in a letter to Nature magazine (October 15, 1874, p. 481) sniped, "There are precidents to justify a hope that it would be no extension beyond the province of Nature, if somebody who knows that molecules possess the essential character of a manufactured article were kindly to explain how he knows a manufactured article when he sees it..." M. Wurtz, in his inaugural address as president of the French Association for the Advancement of Science in 1874, paralleled Maxwell's address of the preceeding year. Wurtz concluded (ambivalently), "It is in vain that science has revealed to it the structure of the world and the order of all the phenomena; it wishes to mount higher, and in the conviction that things have not in themselves their own 'raison d'etre,' their support and their origin, it is led to subject them to a first cause -- unique, universal God" (Nature, Vol. 10, August 27, 1874, p. 350).

frustration, several poems. In one, "Notes of the President's address" (1874, from Campbell, 1882:637ff.) he mused:

> There is nothing but atoms and void, all else
> is mere whims out of date!
> Then why should a man curry favour with beings
> who cannot exist,
> To compass some petty promotion in nebulous
> kingdoms of mist?

In "Song of the Cub," written the same evening of Tyndall's address, he said:

> O where are those high feasts of Science?
> O where are those words of the wise?
> I hear but the roar of Red Lions,[8]
> I eat what their Jackal supplies.

The next day, in "Molecular evolution" he penned:

> Yield, then, ye rules of rigid reason!
> Dissolve, thou too, too solid sense!
> Melt into nonsense for a season,
> Then in some nobler form condense.

Who was closer to the truth, Tyndall or Maxwell? Nothing but a pure faith (as Aquinas held) can decide, within the scope of the argument from perfection. If one wanted a "muscle" argument, one resorted to Kelvin's law of dissipation, but Maxwell would not use that; he remained aloof.

Perhaps his most gentle, yet telling caution concerning Kelvin's derivation of universal "dissipation" from the Fourier equations was given in his "Address to the Mathematical and Physical Sections of the British Association," September 15, 1870 (Niven, Vol. II, 1965:225ff.). After having given all of Kelvin's arguments for the second law from the Fourier equations, he said,

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[8]Red Lions: another name for the British Association, used when the association congregated informally for drink and conversation.

> But the mind of man is not, like Fourier's heated body, continually settling down into an ultimate state of quiet uniformity, the character of which we can already predict; it is rather like a tree, shooting out branches which adapt themselves to the new aspects of the sky towards which they climb, and roots which contort themselves among the strange strata of the earth into which they delve. To us who breathe only the spirit of our own age, and know only the characteristics of contemporary thought, it is as impossible to predict the general tone of the science of the future as it is to anticipate the particular discoveries which it will make.
>
> Physical research is continually revealing to us new features of natural processes, and we are thus compelled to search for new forms of thought appropriate to these features. Hence the importance of a careful study of those relations between Mathematics and Physics which determine the conditions under which the ideas derived from one department of physics may be safely used in forming ideas to be employed in a new department.
>
> (Emphasis added)

If one wants hard physical evidence to stand upon, there is none in the above. There is only a caution about the use of the Fourier equations, and a metaphor about man's mind, trees, and growth (Tyndall had used the same metaphor). A. N. Whithead, whose thought we shall come to in Chapter VII, picked up the same thread, and in The Function of Reason (1929) continued it with respect to the second law.

CHAPTER VI

DEVELOPMENTS ON THE CONTINENT

The scope of this thesis does not permit an extensive treatment of continental thought on the second law. However, the contributions of Clausius, Planck, and Boltzmann in particular are essential to the interpretation of the second law today, and must be included.

Clausius

Clausius developed the second law in Germany over virtually the same time period that Kelvin developed it in England. The two men had some correspondence, and in certain ways the thought of each influenced the other. The mathematical measure of dissipated (or unavailable) energy Clausius called "entropy;" the term is in universal use today. In his "Ninth Memoir" (Poggendorff's Annalen, 1865, in Cardwell, 1971:273), Clausius stated:

> If for the entire universe we conceive the same magnitude to be determined consistently and with due regard to all the circumstances, which for a single body I have called the entropy, and if at the same time we introduce the other and simpler conception of energy, we may express in the following manner the fundamental laws of the universe which correspond to the two fundamental theorems of the mechanical theory of heat.
>
> (1) The energy of the universe is constant
> (2) The entropy of the universe tends to a maximum.

What were Clausius' philosophical thoughts on ever-increasing entropy as a law of the universe? Unfortunately, the surviving historical records are silent. Dr. E. Daub, one of Clausius' recent biographers, has related that Clausius appears to have seen the second law as "consistent with the historical process."[1] Of Clausius' statement in the Ninth Memoir, Cardwell has commented (1971:273):

> This is not a balanced, symmetrical, self-perpetuating universe, as the development of rational mechanics, building on the foundations of Newton's System of the world, seemed so confidently to indicate. It is a universe tending inexorably to doom, to the atrophy of a 'heat death', in which no energy at all will be available although none will have been destroyed; and the complementary condition is that the entropy of the universe will be at its maximum.

Historical data on Clausius is frustratingly scanty. In his biography of Clausius (in Gillispie, Vol. III, 1971:303ff.) Daub states that Clausius received ". . . his early education at a small private school that his father had established and was serving as pastor and principal." However, neither the denomination of the school, nor Clausius' religious affiliation is known. Clausius' middle name is Immanuel, which means "God with us." Dr. Daub has speculated that he may have been Lutheran.[2]

The first half of Clausius' life was professionally the most productive. A leg wound during the Franco-Prussian War, and later family tragedy curtailed his productive work. In his biography of Clausius, Daub (Gillispie, Vol. III, 1971:310) concludes:

> Clausius' great legacy to physics is undoubtedly his idea of the irreversible increase in entropy, and yet we find no indication of interest in Josiah Gibb's work on chemical equilibrium or Boltzmann's views on thermodynamics and probability, both of which were utterly dependent on his idea. It is strange that he himself showed no inclination to seek a molecular understanding of irreversible entropy or to find further applications of the idea; it is stranger yet, and even tragic, that he expressed no concern for the work of his contemporaries who were accomplishing those very tasks.

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[1]Given in personal conversation.

[2]Ibid.

Max Planck

In his Scientific Autobiography (1949:13ff.), Max Planck relates that Clausius' "lucic style and enlightening clarity of reasoning made an enormous impression" on him. Planck considered the second law to be of fundamental significance, and in his Doctoral Dissertation he went on to develop the concept of irreversibility. Elsewhere, Planck has expressed the view that ". . . nature is ruled by a rational, purposive will," incorporating both a "causa efficiens" and a "causa finalis" (Planck, 1949: 177-180). His idea of the importance of irreversibility in thermodynamic processes is harmonious with that outlook. Planck relates his views on the second law and irreversibility as follows (1949:16ff.):

> Clausius deduced his proof of the Second Law of Thermodynamics from the hypothesis that "heat will not pass spontaneously from a colder to a hotter body." But this hypothesis must be supplemented by a clarifying explanation. For it is meant to express not only that heat will not pass directly from a colder into a warmer body, but also that it is impossible to transmit, by any means, heat from a colder into a hotter body without there remaining in nature some change to serve as compensation.
>
> In my endeavor to clarify this point as fully as possible, I discovered a way to express this hypothesis in a form which I considered to be simpler and more convenient, namely: "The process of heat conduction cannot be completely reversed by any means." This expresses the same idea as the wording of Clausius, but without requiring an additional clarifying explanation. A process which in no manner can be completely reversed I called a "natural" one. The term for it in universal use today is: "Irreversible."
>
> Yet, it seems impossible to eradicate an error which arises out of an all too narrow interpretation of Clausius' law, an error against which I have fought untiringly all my life. To this very day, instead of the definition I just mentioned, one often finds irreversibility defined as "An irreversible process is one which cannot take place in the opposite direction." This formulation is insufficient. For it is quite possible to conceive of a process which cannot take place in the opposite direction but which can in some fashion be completely reversed.
>
> . . . in the case of an irreversible process the terminal state is in a certain sense more important than the initial state -- as if, so to speak, Nature "preferred" it to the latter. I saw a measure of this "preference" in Clausius' entropy. . . . I worked out these ideas in my doctoral dissertation at the University of Munich, which I completed in 1879.

Planck's dissertation had a varying reception. He comments that, "Helmholtz probably did not even read my paper at all. Kirchhoff expressly disapproved of its contents . . . I did not succeed in reaching Clausius. He did not answer my letters, and I did not find him at home when I tried to see him in person. . ." (1949:19).

Planck relates that for a long time he was opposed to atomism (and the existence of atoms); and that in his later contacts with Boltzmann, who brilliantly developed atomic theory, ". . . Boltzmann assumed that ill-tempered tone which he continued to exhibit toward me . . . It was only in the last years of his life, when I informed him of the atomistic foundation for my radiation law, that he assumed a friendlier attitude" (1949:33). Planck's experiences finally led him to advance a rather biting theory of scientific advance -- "a remarkable one," in his view: "A new scientific truth does not triumph by convincing its opponents and making them see the light, but rather because its opponents eventually die, and a new generation grows up that is familiar with it."

Planck held definite religious-scientific views. He maintained that "Science and religion, in their ultimate effects, are headed for the same goal, the recognition of an omnipotent intellect ruling the universe . . . The victory of atheism would not only destroy the most valuable treasures of our civilization, but -- what is even worse -- would annihilate the very hope for a better life" (1949:76, 156). "Religion and natural science," he held, "are fighting a joint battle in an incessant, never relaxing crusade against skepticism and against dogmatism, against disbelief and against superstition, and the rallying cry in this crusade has always been, and always will be: '<u>On to God</u>!'" (1949:187).

Ludwig Boltzmann

To a greater extent than anyone else on the continent, Ludwig Boltzmann is credited with the reduction of the classical, macroscopic statement of the second law to statistical-mechanical, atomic assumptions. Boltzmann, working in Vienna in the latter quarter of the nineteenth century, championed atomic theory through the period when it was under heavy attack. Brush relates (1964:12) that during this period, "There was . . . a growing reaction against 'scientific materialism,' and a movement to replace atomic theories by purely descriptive theories based only on macroscopic variables." As a result, Boltzmann's last and most thorough treatment of the subject, his Lectures on Gas Theory (1898) held a polemic flavor. He said (S. Brush, tr., 1964:216), "In my opinion, it would be a great tragedy for science if the theory of gases were temporarily thrown into oblivion because of a momentarily hostile attitude to it . . . I am conscious of being only an individual struggling weakly against the stream of time. But it still remains in my power to contribute in such a way that, when the theory of gases is again revived, not too much will have to be rediscovered." Boltzmann's Lectures on Gas Theory are, comments Brush, ". . . an acknowledged masterpiece of theoretical physics."[3] In it he gave his final reflections on entropy, postulating an entropy-symmetrical universe.

Was Boltzmann a materialist? V. I. Lenin (Vol. XIII, 1927:245) has commented that "Boltzmann was, of course, afraid to call himself a

[3] Sadly, Brush relates (1964:17), "Boltzmann's pessimism about the future of the kinetic theory . . . deepened in the following years, and led to fits of severe depression, culminating in his suicide in 1906. This suicide must be ranked as one of the great tragedies in the history of science, made all the more ironic by the fact that the scientific world made a complete turnaround in the next few years, and accepted the existence of atoms. . . ."

materialist and even made it plain that he had nothing against the Divine Being. But his theory of knowledge is essentially materialistic. . . ." "Consequently," comments Brush (1964:14), "Boltzmann now has the dubious distinction of being a hero of scientific materialism in the eyes of the Marxists." Yet Boltzmann himself does not quite seem to fit that mold. In his foreword to Part I of his Lectures, he gives the keynote statement "Alles Vergangliche Ist nur ein Gleichness!"[4] -- which, translated roughly, "means that all transitory (i.e., earthly) things are only symbols or reflections (of reality)" (Brush, 1964:21). The keynote of the foreword to his Part II (1964:215) reads, "The impossibility of an incompensated decrease of entropy seems to be reduced to an improbability."[5]

Boltzmann did not care for the heat death idea advanced upon the theory of ever-increasing entropy. Of it he said (1964:446), "With all due recognition to the caution which must be observed in going beyond the direct consequences of experience, it must be granted that these consequences (of the second law) are hardly satisfactory, and the discovery of a satisfactory way of avoiding them would be very desirable. . ." He proceeded to offer the following model of the universe (1964:446ff.):

> Application to the universe.
>
> Is the apparent irreversibility of all known natural processes consistent with the idea that all natural events are possible without restriction? Is the apparent unidirectionality of time consistent with the infinite extent or cyclic nature of time? He who tries to answer these questions in the affirmative sense must use as a model of the world a system whose temporal variation is determined by equations in which the positive and negative directions of time are equivalent, and by means of which the appearance of irreversibility over long periods of time is explicable by some special

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[4]From Goethe, Faust, Part II, Act V, final "Chorus Mysticus."

[5]From J. Willard Gibbs (Trans. Conn. Acad. 3, 229, 1875:198 in Ostwald's German edition).

assumption. But this is precisely what happens in the atomic view of the world.

One can think of the world as a mechanical system of an enormously large number of constituents, and of an immensely long period of time, so that the dimensions of that part containing our own "fixed stars" are minute compared to the extension of the universe; and times that we call eons are likewise minute compared to such a period. Then in the universe, which is in thermal equilibrium throughout and therefore dead, there will occur here and there relatively small regions of the same size as our galaxy (we call them single worlds) which, during the relative short time of eons, fluctuate noticeably from thermal equilibrium, and indeed the state probability in such cases will be equally likely to increase or decrease . . . By virtue of this terminology, such small isolated regions of the universe will always find themselves "initially" in an improbable state. This method seems to me to be the only way in which one can understand the second law -- the heat death of each single world -- without a unidirectional change of the entire universe from a definite initial state to a final state. . . .

Phillip Frank (1946:24ff.), considering Boltzmann's interpretation of entropy fluctuation, has commented in the following way:

The sequence "rare state-frequent state" happens as often as "frequent state-rate state". This means that the universe has already traversed a great many cycles. All the rare states have appeared and disappeared and will reappear again. This universe is, in the sense of ancient philosophy, an Epicurean universe. The origin of the sun, the earth, the elements, and even of our own human race is due to the law of chance. . . .

These considerations are pertinent for the attitude of philosophers toward the principles of thermodynamics. A great many philosophic interpretations of physics have made use of the principle of increasing entropy to bolster up an anti-mechanistic teleological view of the universe which invokes a tendency, a direction toward a certain end, instead of a causal chain of events. Unfortunately, the trend of events, if we take thermodynamics for granted, tends toward destruction of the universe. If we, on the other hand, replace pure thermodynamics by the kinetic theory of heat (laws of motion + statistical hypotheses) we . . . accept the Epicurean view that every tendency toward an end is an illusion and the real actor in the evolution of the world is a play of chances and the survival of the fittest. There is no real irrecoverability.

On the other hand, Henry Bent, in his book The Second Law (1965: 135ff.), edits the idea of entropy fluctuations from his presentation of

Boltzmann;[6] gives Boltzmann's measure of entropy together with the statement that it "always increases in a spontaneous process (and) is never negative" (1965:138); and draws no philosophical conclusions.

Bent himself presents an "Obituary" on Maxwell's Demon (1965:76) and elsewhere (1965:52) comments:

> Complete conversion of thermal energy to work is virtually impossible; it is . . . about as likely as the transcription of Shakespeare's complete works by a tribe of wild monkeys punching randomly on a set of typewriters. In all likelihood no one will witness either event; moreover, as once noted, were someone to see thermal energy completely converted to work, or monkey-business turn out Shakespeare, he probably would not believe it. . . .

Bent has taken a definite stance regarding entropy decreases. His views represent the position taken since the turn of the century by other physicists. In her 1959 introduction to The Conceptual Foundations

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[6]In the passage which Bent quotes, Boltzmann had been introducing his entropy-fluctuating cosmos, and contrasting it with the entropy-increasing model from general thermodynamics. Boltzmann's comment is given below; Bent's selection is underlined.

> If therefore we conceive of the world as an enormously large mechanical system composed of an enormously large number of atoms, which starts from a completely ordered initial state, and even at present is still in a substantially ordered state, then we obtain consequences which actually agree with the observed facts; although this conception involves from a purely theoretical -- I might say philosophical -- standpoint, certain new aspects which contradict general thermodynamics based on a purely phenomenological viewpoint. <u>General thermodynamics proceeds from the fact that as far as we can tell from our experience up to now, all natural processes are irreversible. Hence according to the principles of phenomenology, the general thermodynamics of the second law if formulated in such a way that the unconditional irreversibility of all natural processes is asserted as a so-called axiom . . . general thermodynamics (without prejudice to its unshakable importance) also requires the cultivation of mechanical models representing it, in order to deepen our knowledge of nature -- not in spite of, but rather precisely because these models do not always cover the same ground as general thermodynamics, but instead offer a glimpse of a new viewpoint</u>.

(The new viewpoint leads directly to the quotation from Boltzmann given on pages 115-116 of this chapter.)

of The Statistical Method in Mechanics (Leipzig, 1912; N.Y., 1959:x) Tatiana Eherenfest comments, ". . . even today many physicists are still following Clausius, and for them the second law of thermodynamics is still identical with the statement that the entropy can only increase." In the book, she and Paul Eherenfest comment (1959:79):

> Boltzmann . . . explicitly admits cases where the entropy spontaneously decreases. Planck, on the other hand, decides in the opposite way in connection with the same case and, generalizing, emphases the following. The physicist is free to exclude by a special physical hypothesis those deviations which would result in the violation of the uniqueness which is admitted for the macroscopic changes (in time) of a physical phenomenon. Usually the physicist will avoid making a definite decision. He is inclined simply to disregard the strong deviations from the most probable on the basis of their being so "enormously improbable." Or, even more generally, he will refuse to discuss such distant consequences of a physical theory.

This comment may be taken as characterizing orthodox physics since the turn of the century. Entropy decrease has seemed impossible to many.

Yet, within a mere handful of years, the whole question has been reopened by black hole theory and the virtual confirmation of a black hole in Cygnus X-1 last year. It seems almost embarrassing. The black hole, in believable if non-relativistic theoretical form, has been on our back shelf since it was advanced by Laplace in 1796.[7]

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[7]Refer back to pp. 10-12 and p. 18 of the introduction for discussion.

CHAPTER VII

THE PHILOSOPHICAL FOUNDATIONS OF THE SECOND LAW

Introduction

We have covered, in some cases briefly, in others at length, the position of many thinkers on the second law. From the time of Newton onward, British thought has stood forward, making a unique contribution to the dialogue surrounding the law. Particularly is this so with regard to the philosophical foundations of the law, and in this final chapter we will focus on the British tradition, following out some of the reflections of A. N. Whitehead and C. P. Snow.

The Summarizing Table

To begin, let us summarize and locate in tabular form the positions of the writers we have looked at. The table is given on page 120. The writers are located with reference to two conceptual dimensions: (1) belief concerning the objective truth of the second law as a universal principle, and (2) adherence to a particular philosophical-religious outlook. In the table, positions on the second law are given as pro, open and con. These positions are to a degree mutually exclusive, but may be regarded as close to a continuum. The philosophical-religious categories are traditional Christian, optimistic Christian, and materialist. These three terms actually cover a number of possible distinctions.

TABLE 1

Belief Concerning the Objective Truth of the Second Law as a Universal Principle And Adherence to a Particular Philosophical-Religious Outlook

	Traditional Christian	Optimistic Christian	Materialist
Pro	Bentley, R. Chardin, P.T. de Clark, R.E.D. Clausius, R.? St. Cyprian, T.C. Eddington, Sir A. Jeans, Sir J. Lemaitre, A.G.E. Planck, M. Pope Pius XII Stewart, B. Tait, P.G. Whewell, W. Thomson, W. (Lord Kelvin)		Russell, B.
Open	Newton, Sir I.	Aquinas, St. T. Dampier, Sir W.C. (formerly Whetham) Mascall, E.L. Maxwell, J.C.	
Con		Leibnitz, G.W. Whitehead, Sir A.N.	Boltzmann, L. Clifford, W.K. Kuznetsov, P.G. Oparin, A.I. Tyndall, J. Frank, P. Haeckel, E. Laplace, P.

The term materialism is used here to cover a range of outlooks which center around the belief that matter is the real and sufficient substrate of the world. The two religious distinctions are more complex. Generally, the term "traditional Christian" implies personal devotion directed toward a personal God defined by Biblical revelation. The Bible states in addition a specific cosmology (see pp. 34-38) which provides the foundation for the traditional outlook. The term "optimistic Christian" includes a variety of beliefs which share the common concept that the Divine essence sustains the universe in a continuing manner (see particularly p. 40).

The pre-Christian philosophers whom we have considered -- Plato, Aristotle and Democritus -- have been omitted from the table, as the set of ideas underlying discussion of the second law since the start of the Christian era -- those of an absolute beginning and an absolute end of the physical universe, with a linear historical path in between -- were absent from their concepts. Though these men are omitted from the table, it must be said that their thoughts were influential with respect to most of the writers included. Democritus is considered to be a founder of scientific materialism. Plato has powerfully influenced both the traditional and the optimistic strains of Christianity, each strain picking up the mood of the man most congruent with its own outlook. Aristotle stands between these two other philosophers, at least with respect to the passages which were chosen from him.

Two men, Dampier and Whitehead, have been located on the table in anticipation of their views to be given in this chapter. Clausius has been located with a question mark after his name. The men included in the table are listed alphabetically under each philosophical-religious category. The positions of certain men border upon or cut across categories. The positions of Newton and Russell deserve special comment in this regard. Newton, while an orthodox or traditional Christian in many ways, held to the personal outlook that the Lord God was a presently active entity in the universe. As a result, although he was sensitive to the possibility of a "heat death," he in no way advanced it. Russell presents the picture of a man subscribing to philosophical materialism and the second law at the same time. He was not, however, a man advocating the truth of the second law but a man groaning over it.

Discussion of the Table

The first conclusion to be drawn from the table is that the positions of the writers on the objective truth of the second law as a universal principle varied considerably, being predominantly consistent with their religious and philosophical outlook. The professional physicists were no different than the other writers in this respect. This finding is interesting. Presumably, the physicists would be more oriented than the other writers toward the body of factual evidence relevant to the truth or falsity of the second law. The evidence being roughly the same for all, particularly from the 1850's onward, one might expect some convergence of views. Yet the views of the physicists did not converge. Instead they varied with philosophical and religious outlook. Does this variation indicate that the philosophical and religious positions of these men led their physics?

In some sense this appears to be the case. The statements of the physicists on the second law, and here we refer most directly to Kelvin, Tyndall, Clifford, Maxwell, Stewart and Tait (all of whom knew each other personally), were in few ways similar to modern textbook statements on the second law. In the textbook tradition, theory is related to empiric facts and little else. Yet, Kelvin talked less of facts and more of mathematical metaphysics, seeing in the Fourier equations Creation itself. Tyndall snorted about a clockmaker God and propounded Democritean philosophy. Clifford tore into Christianity and misuse of the Fourier equations alike. Maxwell talked of trees, demons, and the mind of man. Stewart and Tait endorsed "dissipation" and tried to replace physical conservation with metaphysical continuity. The statements of these writers hardly fit the textbook model of "doing" physics. The same thing may be said with regard to the thoughts of Newton, Whewell, Boltzmann and Planck.

It is of interest to inquire why this is the case. For one thing, these men were from the outset interested in a great deal more than facts in hand. They were concerned rather with the overall character of the universe. In this task the question was not -- what do the facts in hand prove? -- but rather, what do they intimate? Philosophy and religion provided alternative conceptual frameworks within which the same facts could suggest different conclusions. The conclusion of each man, considered singly, may appear extreme. Stewart and Tait are a particular case in point. In light of such extremity, the textbook model of science -- physics sans philosophy, may appear safer, better. Yet it may be asked whether the philosophical-physical statements of these men might not, <u>when taken as a unified dialogue</u>, be superior to a more astringent empiricism. This last question leads to a consideration of the tradition of philosophical debate in science which historically existed in Britain; its use through the 1880's, its effective demise at the turn of the century, and the efforts of Whithead and Snow in particular to restore it. We will find these men concerned to re-establish a full and rounded dialogue in science; at the same time, we will find them drawn as if by a magnet to the second law. We shall finally ask: is the second law the finished product presented in modern texts, or is it a great and unresolved puzzle, incapable of reformulation without the reunion of philosophy and physics?

The British Tradition

No short exposition, such as this one must be, can properly treat the subject next to hand. A brief view of certain aspects, a few examples to help the imagination -- these must suffice to reconstruct in the reader's eye "an heroic age in science" (Eiseley, 1961:20).

At the beginning of the nineteenth century England had, with respect to science, two cultures: one to be found in the country at large, the other shared by a relative handful of highly trained (if parsimoniously supported) men, cloistered in the universities. England had begun to industrialize, but she was virtually unaware of the need for a large-scale science to undergird these efforts. In the early part of the century, the British men of science started to do something extraordinary about that situation. They organized to sell an entire nation -- not merely on science, but on scientific thought as a way of life. To a significant degree, they succeeded, and it is of interest to discover the elements leading to that success.

The type of education which these men received was one element. They were drilled in Greek, Latin and the classics, and were acquainted with the great philosophical and religious systems of history. On the other hand, mathematics was undergoing development, and a complex, mathematical dialogue in physics was emerging. Empirical enquiry was receiving emphasis. Mathematics and empirics combined to produce an increasingly technical science. More and more such science required specialization, more and more it seemed to auger the later split between what are now called the humanities and the sciences. But the split had not yet occurred. Physical science was still 'natural philosophy.'

Education was grueling, being as much a contest in sheer endurance, in ability to overcome the insatiate demands of the "angry bell" as anything else. While a Cambridge student, Maxwell wrote exhaustedly (Campbell, 1882:631):

> Late to bed and early rising,
> Ever luxury despising,
> Ever training, never "sizing,"
> I have suffered with the rest. . .

In class, stern discipline presided over a competitive format. The classes which Kelvin himself taught are illuminating in this regard. Gray (1908:95) relates that Kelvin felt "oral examination and the training of individual students in the art of clear and ready expression" to be essential.[1] Kelvin had, in his turn, undergone "oral examination" in

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[1]Gray, himself a student of Kelvin's relates some memories on this point (1908:281ff.):

> The writer will never forget the lecture-room when he first beheld it, from his place on Bench VIII, a few days after the beginning of session 1874-5. Sir William Thomson, with activity emphasised rather than otherwise by his lameness, came in with the students, passed behind the table, and, putting up his eye-glass, surveyed the apparatus set out. Then, as the students poured in, an increasing stream, the alarm weight was released by the bell-ringer, and fell slowly some four or five feet, from the top of the clock to a platform below. By the time the weight had descended the students were in their places, and then, as Thomson advanced to the table, all rose to their feet, and he recited the third Collect from the Morning Service of the Church of England. . . .

his father's class, and it was a training to think on one's feet, under adverse and searching query. Such thinking involved not only facts and mathematics, but broadly philosophical theory as well. Kelvin felt that ". . . in science there were two stages of progress -- a natural history stage and a natural philosophy stage" (Gray, 1908:88). In the latter stage comprehensive theory was developed, and he placed few strictures on such development. "Science is bound," Kelvin said, "by the everlasting law of honour, to face fearlessly every problem that can fairly be presented to it" (Thompson, Vol. II, 1910:1011).

To Kelvin, theoretical debate was meat and drink. Stimulated, he would "brainstorm" at top speed. Gray relates that he was "inspiring

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> Then the Professor began his lecture, generally with the examination of one of the students, who rose in his place when his name was called. . . . The names of the students to be questioned were selected at random from the class register, or by a kind of lottery, carried out by placing a small card for each student in a box on the table, and drawing a name whenever a member of the class was to be examined. The interest in the drawing each day was intense, for there was a glorious uncertainty as to what might be the line of examination adopted. Sometimes in the midst of a criticism of an answer, an idea would suddenly occur to the Professor, and he would enlarge upon it, until the forgotten examinee slipped quietly back into his seat, to be no more disturbed at least for that day! And how great the relief if the ordeal was well passed and the card was placed in that receptacle of the blessed, the compartment reserved for those who had been called and duly passed the assize! But there was a third compartment reserved for the cards of those unfortunates who failed to satisfy the judge! The reader may have anticipated the fact that the three divisions of this fateful box were commonly known to students by the names of the three great habitations of spirits described in the Divina Commedia of Dante. . . . The ordeal was dreaded by backward students, whom Thomson found, as he said, aphasic, when called on to answer in examination, but who certainly were anything but aphasic in more congenial circumstances. Occasionally they abstained from responding to their names, modestly seeking the seclusion of the crowd, and some little time would be spent in ascertaining whether the examinee-designate was present. When at last he was discovered, he generally rose with a fervent appeal to his fellows on either side to help him in his need.

to the best students . . . his enthusiasm infectious. But with the ordinary student . . . he was not so successful. He saw too much while he spoke; new ideas or novel modes of viewing old ones presented themselves unexpectedly, associations crowded upon his mind, and he was apt to be discursive, to the perplexity of all except those whose minds were endued also with something of the same kind of physical instinct or perception" (1908:311). But Kelvin had little time for the ordinary student. He, like the system of education around him, was concerned with training that small group of greatest ability.

If Kelvin was the autocrat of his classroom,[2] he held his students in a sense of nervous excitement and dramatic stimulation. He passed strong judgment on both people and ideas, and his demonstrations tended to be attention-getters. One demonstration involved discharging a Jacob (big game) rifle in the classroom. Gray comments (1908:288),

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[2]Gray relates (1908:287):

> On one occasion, after working out part of a calculation on the long fixed blackboard on the wall behind the table, his chalk gave out, and he dropped his hand down to the long ledge which projected from the bottom of the board to find another piece. None was just there; and he had to walk a step or two to obtain one. So he enjoined McFarlane, his assistant, who was always in attendance, to have a sufficient number of pieces on the ledge in future, to enable him to find one handy wherever he might need it. McFarland forgot the injunction, or could not obtain more chalk at the time, and the same thing happened next day. So the command was issued, "McFarlane, I told you to get plenty of chalk, and you haven't done it. Now have a <u>hundred</u> pieces of chalk on this ledge to-morrow; remember, a <u>hundred</u> pieces; I will count them!" McFarlane, afraid to be caught napping again, sent that afternoon for several boxes of chalk, and carefully laid the new shining white sticks on the shelf, all neatly parallel at an angle to the edge. The shelf was about sixteen feet long, so that there was one piece of chalk for every two inches, and the effect was very fine. The class next morning was delighted, and very appreciative of McFarlane's diligence. Thomson came in, put up his eye-glass, looked at the display, smiled sweetly, and, turning to the applauding students, began his lecture.

"The front bench students were always in a state of excitement, mingled in some cases perhaps with a little trepidation. For the target was very near them . . . the solemn stillness with which the aiming and adjustments had been witnessed was succeeded by vociferous applause." In another favorite demonstration, the "dew Drop," Kelvin slowly filled a rubber membrane with water, until it grew quite large. He would lecture on surface tension while it grew ever larger, nudging it gently with a pointer the while. It finally burst. Gray notes (1908:291), "A large tub had been placed below to receive the water, but the deluge always extended over the whole floor space behind the table, and was greeted with rapturous applause."

These nostalgic tales of Gray's illustrate a point of importance. Kelvin placed a premium on capacity for "clear and ready expression" by a student under fire. He was a keen theorist, and he gave eye (and ear) popping demonstrations. As well as being a mathematical empiricist, Kelvin was a natural philosopher, a debator, and a dramatic showman. These latter talents would become vital in selling science to the nation as a whole.

Kelvin was not alone among the British men of science in holding and exercising such talents. The educational tradition of the British men of science virtually ensured that there would be a well-rounded "top" group, which thrived on strong debate. (Competition for the positions of first and second wrangler in the tripos, or final examinations, served to emphasize that debating outlook.[3])

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[3]Throughout his life, Kelvin rankled over having come out second wrangler.

Kelvin, Tyndall, Tait, Stewart, Clifford, Huxley, and many others were men of the above tradition. (Maxwell was less inclined to strong debate, being more the gentle poet.) Now this training and orientation might have produced no more than some brilliant "pedantry" as Maxwell called it, in small circles behind college walls. It has been held that in fact it did, with respect to the tripos. However, beginning in the 1820's a further ingredient was infused into the situation. The scientists began to claim, and increasingly gained, the attention of the British nation. This audience in turn affected the scientists.

In the 1830's the British Association for the Advancement of Science was founded. Shortly thereafter, Nature nagazine was started, and it served as the mouthpiece of the Association. The magazine was unique. It provided a "round table" for discussion and contribution by professional and amateur alike. The magazine carried full reports of the meetings and addresses of the Association, the special nature walks, lectures and outings which they sponsored, and the comments -- scientific, humorous, and personal -- that came in from all quarters. For instance, a ladies' garden club noticed and wrote in to the magazine about a rare double rainbow they had seen; Maxwell had seen it from another place, and he wrote the following week in response. When Kelvin put forth his "meteoric" theory about how life had developed on earth (in his 1871 Presidential address to the Association), all types of comment appeared in the magazine. One fellow, identifying himself only as G. E. D. (Nature, August 17, 1871:305), snapped at Kelvin ". . . we know all about you, old boy, and the British Association; and we don't think much about you, either." Maxwell contributed a poem kidding Kelvin (Nature, August 10, 1871:291), whom he called "a swell profound." The poem reads in part:

THE BRITISH ASS[4]

(Sung by a Cub at the Red Lions' Feed, Edinburgh, August 7, 1871)

Air: "THE BRITISH GRENADIERS"

Some men go in for Science,
   And some go in for Shams,
Some roar like hungry Lions,
   And others bleat like lambs;
But there's a Beast that at this Feast
   Demands a special glass,
So let us bray, that long we may
   Admire the British Ass!
      With a tow, row, row, &c, &c.

On Grecian senses charming
   Fell the music of the spheres,
But voices more alarming
   Salute our longer ear.
A swell profound doth now propound
   How life did come to pass,
From world to world the seeds were hurled,
   Whence sprung the British Ass!

In our wandering through Creation
   We meet these burning stones,
That bring for propagation
   The germs of flesh and bones
And is it not a thrilling thought
   That a huge misguided mass
Will come some day to sweep away
   Our dear old British Ass!

The child who knows his father
   Has aye been reckoned wise,
But some of us would rather
   Be saved that sweet surprise,
If it be true that when we view
   A comely lad or lass,
We find the trace of the monkey's face
   In the gaze of the British Ass!

The "British Ass," as Maxwell dubbed it, became unique. It courted Lord, lady and labourer alike. The men of the Association came to see it as a duty to lecture to the working men in the mills,[5] and they

[4]The "British Ass" was Maxwell's term for the British Association.

[5]Eiseley comments (1967:12): "In their day science, if it was to receive public acceptance and support, could not afford the luxury of the cloister or the aloof arrogance of an institutionalized bureaucracy. Men had to speak to men."

invited them along with dignitaries, captains of industry and "swells" to attend the meetings and activities of the Association. As we noted in the last chapter, over 1,800 people (of them, 600 ladies, gloated a reporter in Nature) attended Tyndall's 1874 address to the Association. Such attendance became typical; the whole movement became a social phenomenon.

All this was bound to have effects. The first effect was on the mode of British science itself. Mathematics and professional expertise was in it, but at the same time this science had to be expressed in the literate mode. The British men of science rose to the occasion. As Barzun (1941:74) comments, "A new beauty was being given man to enjoy -- scientific eloquence, of which Huxley and Tyndall were in English the two great creators." Huxley, comments Eiseley (1967:10), ". . . remarked that literature and science were not two separate things but rather the two sides of a single coin." With the literate mode joined to the scientific, a further fusion developed. History and philosophy were related to the burning issues of the present.

On the stage of the British Association, and before a mounting public, the British men of science debated those issues in earnest. Many results came of the debates. Before the turn of the century science as a way of life had gained wide acceptance, and British scientists won greatly increased financial support. The philosophy of many people came to be changed forever. But if there was progress, it appears there was also tragedy. For it happened upon the stage erected by the British Association, that scientific materialism and traditional Christianity strode forward, and in full view of everyone nearly killed each other.

The issue turned upon evolution. It is a story we cannot tell here, but certain elements of the matter must be looked at. It was not evolution per se which caused heartache, but rather the idea that random genetic variations were selected for survival by the operation of <u>mindless</u> natural forces. In this view, as Bertrand Russell later commented, "Man is the product of causes which had no prevision of the end they were achieving." To men who believed they had been fashioned by divine intelligence, and who therefore existed for some ultimate reason and purpose, the idea was disastrous. "Did I not believe," related a friend to Tyndall, "that an Intelligence is at the heart of things, my life on earth would be intollerable" (<u>Nature</u>, August 20, 1874:310). Yet Darwin had developed so many lines of evidence that the intolerable conclusion seemed certain. T. H. Huxley, "Darwin's bulldog," drove the idea forward relentlessly. Man, no longer child of the divine, one again was thrust from the garden, this time to become merely an animal among animals. What sort of morality dominated an animal world? In "The Struggle for Existance in Human Society" (1888, in Kropotkin, 1914:329) Huxley stated,

> From the point of view of the moralist the animal world is on about the same level as a gladiator's show. The creatures are fairly well treated, and set to fight -- whereby the strongest, the swiftest and the cunningest live to fight another day. The spectator has no need to turn his thumbs down, as no quarter is given. He must admit that the skill and training displayed are wonderful. But he must shut his eyes if he would not see that more or less enduring suffering is the mead of both vanquished and victor. And since the great game is going on in every corner of the world, thousands of times a minute; since, were our ears sharp enough, we need not descent to the gates of hell to hear --
> sospiri, pianti, ed alti guai.
> . . . .
> Voci alte e finoche, e suon di man con elle
> -- it seems to follow that, if the world is governed by benevolence, it must be a different sort of benevolence from that of John Howard.[6]

[6]John Howard: a British reformer of the period.

Men seemed plunged irrevocably into a world which the church had taught for centuries to be corrupt. Newtonian physics was beginning to build a different picture of the world -- but it was, we know now, a bare beginning, treating only of mass, force, motion and space. It demonstrated only mechanism and efficient cause, power and force. It was no substitute for the higher visions of the religious mind, or even the higher visions of the materialist. What resulted might have been foreseen. Barzun (1941:100) writes:

> While some of the best minds were whirling round and round in this vicious circle, it was not noticed that the words Matter and Force, particularly when applied to human beings, might find in daily life some dangerously simple applications. No one can continue preaching the sole reality of these "bare facts" without encountering someone who will take him literally. And when the idea of force is embodied in the notions of Struggle and Survival of the Fittest, it should be expected that men will use these revelations of science as justifications for their own acts. Darwin did not invent the Machiavellian image that the world is the playground of the lion and the fox, but thousands discovered that he had transformed political science. Their own tendencies to act like lions and foxes thereby became irresistible "laws of nature" and "factors of progress," while moral arguments against them were dubbed "pre-scientific." The only text they would heed was "Go to the ant, thou sluggard," because ants waged wars.
>
> War became the symbol, the image, the inducement, the reason, and the language of all human doings on the planet. No one who has not waded through some sizable part of the literature of the period 1870-1914 has any conception of the extent to which it is one long call for blood, nor of the variety of parties, classes, nations, and races whose blood was separately and contradictorily clamored for by the enlightened citizens of the ancient civilization of Europe.

It is a sad fact, but when man discovered himself to be a child of nature, he did not revise his opinion of nature upward. Revision went the other way. Could things have been different? As a youth of twenty-eight, Darwin had written (Eiseley, 1961:352):

> If we choose to let conjecture run wild, then animals, our fellow brethren in pain, disease, suffering and famine -- our slaves in the most laborious works, our companions in our amusements -- they may partake of our origin in one common ancestor -- we may be all melted together.

That might have been the message of evolution; instead came bloody monkey business.

In the face of reductionistic materialism, Tyndall asked (Vol. II, 1902:97), ". . . had we not better recast our definitions of matter and force; for, if life and thought be the very flower of both, any definition which omits life and thought must be inadequate, if not untrue. Are questions like these warranted? Why not?"

Tyndall, Darwin and Huxley came to agonize over the deadly fallout of their ideas. In his Romanes Lecture on Evolution at Oxford in 1894, Huxley held that "Capital and labor, nation and nation, race and race, must live otherwise than as the ants. Co-operation and love, the Sermon on the Mount, were the more successful, the more 'scientific' ways of life" (Barzun, 1941:111ff.). But his earlier ideas had settled in the public mind. Barzun comments, "His speech was taken by some as a 'senile recantation.'"

The materialistic reductionism that emerged in that century verges on the incredible. All the more does this seem so if one goes back to Democritus, Epicurus and Lucretius. Their "materialism" was hardly the materialism of the nineteenth century; for while there were only 'atoms and the void', there were also special atoms of which the soul was composed, with the capacity for making 'free swerves' (Reese and Freeman, eds., 1964:393ff.). The idea may seem strange to us today. Yet its intent should be clear enough; for those philosophers mind, freedom, purpose were as fully in the world as matter itself. Yet the mechanical materialism of the nineteenth century repudiated such equal presence. The mind and its qualities became a mere "epiphenomenon" of determinate matter. It is curious; Diogenes Laertius, writing of Epicurus' materialism had said (Reese and Freeman, eds., 1964:389):

> Destiny, which some introduce as sovereign over all things, he /Epicurus/ laughs to scorn, affirming that some things happen of necessity, others by chance, others through our own agency. For he sees that necessity destroys responsibility and that chance or fortune is inconsistant; whereas our own actions are free, and it is to them that praise or blame naturally attach. It were better, indeed, to accept the legends of the gods than to bow beneath that yoke of destiny which the natural philosophers have imposed. The one holds out some faint hope that we may escape it if we honour the gods, while the necessity of the naturalists is deaf to all entreaties.

That statement might have been addressed to the Nineteenth century. Between the materialism of that time and Christian belief, "It were better, indeed, to accept the legends of the gods. . . ."

Kelvin and Maxwell, for example, looked from nature to God as the source of life and its unique qualities. To Kelvin, material reality -- "the fortuitous concourse of atoms" -- was "powerless to account for the directed operations of living matter, /and/ the demonstrated daily miracle of our human free-will" (Thompson, Vol. II, 1910:1093). Maxwell was similarly unable to see freedom and purpose as products of matter. Of Lucretius' atomic universe, held fast by fate, "Ruining along the illimitable inane," he said (Niven, ed., Vol. II, 1965:373):

> It is no wonder that he /Lucretius/ should have attempted to burst the bonds of fate by making his atoms deviate from their courses at quite uncertain times and places, thus attributing to them a kind of irrational free will, which on his materialistic theory is the only explanation of that power of voluntary action of which we ourselves are conscious.

Kelvin's and Maxwell's views illustrate the dilemma of many sincere Christians of that period. Taught, as Tyndall said, to "scorn the earth," and value the gifts of life as coming uniquely from God, it was simply impossible to accept those same gifts from nature. Traditional Christianity had insisted too long that nature's impotence argued God's existence.

And so, when men were driven towards materialism, they found no place for their most cherished values. Over centuries, the dualistic teaching of the church had "reduced" materialism, thereby hobbling it. Similarly, in the nineteenth century, scientific materialism crippled the belief system of traditional Christianity. Church dogma left the evolutionary field of battle on crutches. Speaking of this period, Lynn White, Jr., writes (1968:49):

> The new biology destroyed the symmetry of Christian history which had been designed by the devout to explain the Incarnation. Consequently, in the opinion of many men, the entire structure collapsed, and faith in the singleness and purpose of the time process waned. Under the aging Victoria, there occurred a shift in the world outlook of Europe and America more important than any since the days of Constantine. If the latter marked the beginning of the middle ages, historians of the future, gifted with a perspective denied us today, may well conclude that the former marks their true end.

What happened to the great philosophical-scientific debates promulgated by the British Association? Having berthed an infant -- deterministic Darwinism -- which some today might call 'Rosemary's baby', they faded slowly away. And, it might be added, during just that period when their continuation was most needed. A new and less reductionistic synthesis could have emerged, but it was not to be at that time. Starting in the 1880's a reaction to scientific materialism set in. Also, by this time physical scientists had achieved increased funding. Suddenly, there were a host of new 'facts' which could be chased, and what Kelvin called the "first stage" of science blossomed. More than ever, the opening words to Dickens' <u>Hard Times</u> -- "Now, what I want is, Facts" -- seemed appropriate. Empiricism and positivism grew. Philosophically, they attempted to be neuter. Touch a positivist with philosophy and he fairly shrieked. Numbers of philosophers sat around and analyzed the meaning of words.

Certain men, such as A. N. Whitehead and more recently, C. P. Snow in England have tried to put Humpty Dumpty together again, and we shall look at some of their thoughts shortly. Certain of their writings possess an almost desperate urgency, as if they saw us to be in a race which might be lost. Perhaps they have been haunted by Plato's ghost. Or, perhaps, Huxley's.

In 1895, as president of the Royal Society, Kelvin spoke of the death of Huxley. The two men had been almost diametrically opposed, philosophically. One might expect a certain feeling in Kelvin's words. He said (Thompson, Vol. II, 1910:1088):

> Even those purely scientific papers [of Huxley's] contain ample evidence that Huxley's mind did not rest with the mere recording of results discovered by observation and experiment: in them, and in the nine volumes of collected essays which he has left us, we find everywhere traces of acute and profound philosophic thought. When he introduced the word agnostic to describe his own feeling with reference to the origin and continuance of life, he confessed himself to be in the presence of mysteries on which science had not been strong enough to enlighten us; and he chose the word wisely and well. It is a word which, even though negative in character, may be helpful to all philosophers and theologians. If religion means strenuousness in doing right and trying to do right, who has earned the title of a religious man better than Huxley?

Reflections on the British Tradition

T. H. Huxley did more perhaps than any other man to strike at the religious viewpoint which Kelvin held dear. Yet in the end Kelvin spoke of his 'doing right and trying to do right,' and called him a religious man. Kelvin's statement about Huxley reveals the relationship between certain men of the British Association for the Advancement of Science in that age. Those men used uncompromising words in criticizing each others scientific views. Recall Tyndall's rejection of Maxwell's theory of creation. Recall Kelvin's propensity for unsparing comments. Recollect

Maxwell's poem joshing Kelvin and his discomfort over evolution. Remember Clifford's dreadfully blunt response to Tait's position in The Unseen Universe. Yet, Tait and Clifford were personal friends and remained so. Something of a similar nature can be said about other men in the Association. While hard debators, they were joined in something which went beyond debate.

In casting about for some analogy to the relationship of these men, a chapter from a novel comes to mind. It is in T. H. White's "The Once and Future King." Let us look on with the Wart (King Arthur as a boy) as he observes, through Merlin's magic, a battle between King Pellinore and Sir Grummore Grummursum (White, 1966:59ff.):

> "How-de-do?" inquired Sir Grummore.
> "Hail," said King Pellinore. "No, I mean it won't hail, will it?"
> "Nice day," said Sir Grummore.
> "Yes, it is nice, isn't it, what?" . . .
> "Been questin' today?"
> "Oh, yes, thank you. Always am questing, you know. After the Questing Beast."
> "Interestin' job, that, very."
> "Yes, it is interesting. Would you like to see some fewmets?"[7]
> "By Jove, yes. Like to see some fewmets."
> "I have some better ones at home, but these are quite good, really."
> "Bless my soul. So these are her fewmets."
> "Yes, these are her fewmets."
> "Interestin' fewmets."
> "Yes, they are interesting, aren't they? Only you get tired of them," added King Pellinore.
> "Well, well. It's a fine day, isn't it?"
> "Yes, it is rather fine."
> "Suppose we'd better have a joust, eh, what?"
> "Yes, I suppose we had better," said King Pellinore, "really."
> "What shall we have it for?"
> "Oh, the usual thing, I suppose. Would one of you kindly help me on with my helm?" . . .
>
> [An awful battle ensued. The two knights finally unhorsed each other and came to stand face to face.]

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[7]Fewmets: droppings.

"Defend thee," cried King Pellinore.

"God save thee," cried Sir Grummore.

With this they drew their swords and rushed together with such ferocity that each, after dealing the other a dint on the helm, sat down suddenly backwards.

"Bah!" cried King Pellinore.

"Booh!" cried Sir Grummore, also sitting down.

"Mercy," exclaimed the Wart. "What a combat!"

. . . The trees shook, the forest rang. Blackbirds and squirrels cursed and wood-pigeons flew out of their leafy perches half a mile away. The two knights stood to attention while one could count three. Then, with a last unanimous melodious clang, they both fell prostrate on the fatal sward.

"Stunned," said Merlyn, "I should think."

"Oh, dear," said the Wart. "Ought we to get down and help them?"

"We could pour water on their heads," said Merlyn reflectively, "if there was any water. But I don't suppose they would thank us for making their armour rusty. They will be all right. Besides, it is time that we were home."

"But they might be dead!"

"They are not dead, I know. In a minute or two they will come round and go off home to dinner."

"Poor King Pellinore has not got a home."

"Then Sir Grummore will invite him to stay the night. They will be the best of friends when they come to. They always are."

"Do you think so?"

"My dear boy, I know so. Shut your eyes and we will be off."

Echoes of Arthur's Court ring through the scientific debates of the nineteenth century; a bit of Sir Grummore and King Pellinore were in the men of that time. As Eiseley remarked, it was an heroic age in science. Many of the scientists were, like Pellinore, "After the Questing Beast." They had fewmets, evidence to show, and there were always "better ones at home." But it was the strife of great debate that irresistibly attracted them, and with jousting stance they battled back and forth before the British public.

Considering Kelvin's statement of the second law in relation to the social pattern of science at that time, it appears to have been an intellectual weapon, sharpened for use in the lists of Christianity. Kelvin had used the extraordinary term "impossible" in stating the second law. In virtually the same breath, he added qualifiers such as "known" facts, "unles operations have been, or are to be performed. . ." and so forth. Kelvin's statement of the second law was dramatic. Rather than quietly saying, "Here is an hypothesis. . ." he said, "this is impossible, unless. . ." What has happened since his time? Where Kelvin is quoted in the modern physics text, only the term "impossible" survives. Not only is Kelvin mis-quoted by omission, so that his religious ideas are obscured, he is quoted without reference to the debates of his times. He seems to be taken as speaking in a pure (if scientific) vacuum.

It can be said of that period, what got picked out of Darwin was not quite Darwin; what got abstracted out of Huxley was not quite Huxley, nor was that which was taken out of Tyndall -- quite Tyndall. The same holds for Kelvin. Only those points most sharpened for debate seemed to hang in the hide of the audience. Then, before the damage could be undone, the show got closed. If anything comes out of reading history on this matter, it is that the statements of debators should be taken within the context of their dialogues. (Can one reach a good conclusion on a legal case by reading only the defense, or the prosecution?) The second law, as stated in the 1850's, must be considered in terms of the contributions of Clifford, Tyndall, Maxwell -- and yes, Tait and Stewart, as well as Kelvin. In such manner a rounded picture of the law's strength and weakness emerges. Yet, by the start of the twentieth century only a rather truncated version of Kelvin's statements had become dominant. That version was incorporated into the cosmology of Jeans and Eddington. Was this really warranted? Dampier, writing in 1929 commented (1949:300):

> The application of the principles of thermodynamics to cosmic theories, at all events on nineteenth-century evidence, was of doubtful validity. It was unjustifiable to extend to the universe results inferred from such limited instances, even though they had

> been successfully used to predict the behavior of finite isolated or isothermal systems.[8]

How is it that a philosophically and religiously inspired hypothesis, which far outran (and continues to outrun) the evidence in hand, came to be set as the inevitable and only conclusion to be drawn from that evidence?

We have said that the British Association experienced a tragedy toward the close of the nineteenth century. There had also been tragedy in Camelot. The tradition of the round table did not hold, and its power was scattered. In the case of late nineteenth-century science, when the breakup came, mathematical empiricism went one way while literature, history and philosophy went another. Empiric science, in turn, was embarrassed to point to anything other than its gathered fewmets as the basis of its conclusions. As a result, not just the second law, but other scientific theories were paraded as the inevitable conclusion of fact while their philosophical roots, which could have been examined and challenged, went unnoticed.

In his Gifford Lectures at the University of Edinburgh in 1927, Eddington had announced that the second law held "the supreme position among the laws of Nature" (Eddington, 1963:74). In his Vanuxem Foundation lectures at Princeton in 1929 (since reprinted as The Function of Reason), A. N. Whithead launched an attack on both the separation of philosophy and science, and the second law as a universal principle.

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[8] In evaluating Dampier's position on the second law, it must be noted that he rejects both materialism and traditional orthodoxy in science. He sees God's action as continuing: "Creation must be regarded as a continuous process . . . There is still room -- indeed the whole universe -- for a sense of awe and mystery, still room for reverent inquiry, for faith in things unseen. Instead of the childish story of the six days, with their separate acts of creation, the real problem of Being (arises) stupendous, overwhelming" (1949:311).

With respect to the first subject he said reflectively (1962:50ff.):

> The separation of philosophy and natural science . . . is indicated by the division of science into 'moral science' and 'natural science.' For example, the University of Cambridge has inherited the term 'moral science' for its department of philosophic studies. The notion is that philosophy is concerned with topics of the mind, and that natural science takes care of topics concerning matter. The whole conception of philosophy as concerned with the discipline of the speculative Reason, to which nothing is alien, has vanished . . . The modern doctrine, popular among scientists, is that science is the mere description of things observed . . . . Thus the quest of science is simplicity of description. The conclusion is that science, thus defined, needs no metaphysics. We can then revert to the naive doctrine of the University of Cambridge, and divide knowledge into natural science and moral science, each irrelevant to the other.

Speaking of the second law, he said (1962:29ff.):

> This empirical fact constitutes one of the deepest unsolved mysteries. . . . Science has always suffered from the vice of overstatement. In this way conclusions true within strict limitations have been generalized dogmatically into a fallacious universality . . . Our scientific formulation of physics displays a limited universe in process of dissipation. We require a counter-agency to explain the existence of a universe in dissipation within a finite time. . . . We have omitted some general counter-agency.

In the operation of the human mind he found one of those agencies. "Reason," he said, "is the special embodiment in us of the disciplined counter-agency that saves the world." Urging the use of a philosophically trained speculative reason, he said (1962:56), "It finally proceeds to predict, on the basis of . . . the facts thus described, the observability of occurrences generically different from any hitherto made."[9] Whitehead asked urgently for a reunion of philosophy and physics. He all but said that the second law was a bad problem left lying on the floor by their separation, and suggested that the use of the speculative reason would lead to the discovery of generically different phenomena.

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[9]The publishers of the 1962 edition of The Function of Reason note that it has been "Long out of print."

In 1959, C. P. Snow delivered the Rede Lecture at Cambridge, which he entitled "The Two Cultures." He argued that (1965:17), ". . . our fanatical belief in specialization (has precipitated) two cultures . . . already dangerously separate sixty years ago." In "The Two Cultures -- A Second Look" (1965:60), Snow summarized his main points as follows:

> In our society (that is, advanced western society) we have lost even the pretense of a common culture. Persons educated with the greatest intensity we know can no longer communicate with each other on the plane of their major intellectual concern. This is serious for our creative, intellectual and, above all, our normal life. It is leading us to interpret the past wrongly, to misjudge the present, and to deny our hopes for the future. It is making it difficult or impossible for us to take good action.
>
> I gave the most pointed example of this lack of communication in the shape of two groups of people, representing what I have christened 'the two cultures.' One of these contained the scientists . . . the other contained the literary intellectuals . . . between these two groups -- the scientists and the literary intellectuals -- there is little communication and, instead of fellow-feeling, something like hostility.

Snow continued (1965:71):

> . . . I used as my test question about scientific literacy, <u>What do you know of the Second Law of Thermodynamics</u>? It is, in fact, a good question. Many physical scientists would agree that it is perhaps the most pointed question. . . .

Snow reported that the response to this question "was cold; it was also negative" (1965:15).

It is only accident that both men write about a split in the culture -- Whitehead about the split between science and philosophy, Snow about the split between science and the literate intellectual, and then together turn to thoughts on the second law? Might something important have slipped betwixt the cup and the lip, these last eighty years? In the following section, which concludes this paper, I should like to argue that it has.

Conclusion, and an Argument from Clifford's Corner

W. K. Clifford provided one of the most trenchant reasons ever given for the limitation of the second law. He was also an unsparing critic of traditional Christianity (Vol. I, 1901:268ff.). His position has not been advanced lately, and so in the interest of stimulating discussion, I am going to act as advocate of that position and give it a modern development. The statements I will make will be neither neutral, nor necessarily true. I frankly hope to arouse a debating spirit in those who read this paper.

The first and second laws of thermodynamics, stating respectively the conservation and the dissipation of energy, are considered by many to be the two most fundamental laws of the universe. Both laws are held to be empirically derived. Yet, upon reflection, it does not seem possible to state, from the limited empiric evidence available, either proposition as a universal law. Another element appears to be involved in such statement -- religious and philosophical belief. It has been held by many writers that the two most influential streams of thought shaping the modern world are the Greek and the Christian philosophies. Conservation was a fundamental principle of Greek philosophy, and it implied the eternity of the universe. The second law, on the other hand, implied Creation in time past, and appears overwhelmingly Christian in its inspiration.

Unbroken conservation on the one hand, and Creation, with steady consequent dissipation on the other hand, are ultimately contradictory postulates. Yet both co-exist in the belief system of modern physics, the contradictions having been swept under the carpet of the past.

If we examine the conservation and the dissipation principles, we find that they imply very different things about the character of the universe. Upon the conservation principle, it is possible to say that the world is a self-sufficient material reality, devoid of all divinity. It is equally possible to conclude that the God-principle provides unbroken and continuous support for the universe. There appear to be certain foundations for both inspirations; the matter has not been brought to a conclusion.

If we turn to the second law, a very different picture emerges. The origin of the universe, through a creative act of God in the remote past, comes to be shrouded in impenetrable mystery. Its present operation is seen to be less than self-sustaining, and its future is eternal stagnation. This is an unsatisfactory situation, just from the standpoint of the religious outlook. As Eddington, one of the champions of the second law has said (1959:59): "Even those who would welcome a proof of the intervention of a Creator will probably consider that a single winding-up (of the universe) at some remote epoch is not really the kind of relation between God and his world that brings satisfaction to the mind." If we look backwards from the Christian era to the time of archaic man, we find something similar to the second law held as a belief. The world was thought to be cyclical in nature. A tribal god or pantheon of gods initiated each cycle through sacrifice or sexual union with the earth, which in turn was viewed as passive.[10] After initiation of the new cycle, the gods withdrew. Degeneration, for example from the gold to the

[10]Today we still recognize the passivity of nature, and its incompleteness, through use of the term "mother nature" rather than father nature. Consider, for example, the principle of the Yin and the Yang. Also, see Eliade (1959:144ff.) on "the hierogamy between the Sky-God and Mother Earth."

iron age, occurred in the absence of the gods, who eventually returned to end the old cycle and recreate a new one. This precept of degeneration within each cycle is the first recognition of the second law. Such beliefs on the part of archaic man were usually accompanied by rituals of worship and sacrifice, frequently human (Frazier, 1966; Eliade, 1959). Against primitive worship and sacrifice the majority of the Greek philosophers developed their precepts. Democritus and Epicurus, fully as much as Plato, recoiled from popular superstition. Their universe became predominantly a world of principle, law and harmony, characterized by conservation. The most important aspect of it was ultimate unity. If a divinity existed, it existed with and was a part of the cosmos.

In distinction to such ideas, Christianity reaffirmed the basic dualism of a God who antedated and was separate from the world, and who "Created" that world in time. It held that (see p. 36):

> God alone has no beginning but always is and always will be; the eternal God is the one and only principle of all things, 'Creator of all things visible and invisible, spiritual and corporeal; by His almighty power, at the beginning of time He created both orders of creation alike out of nothing.

In this view, conservation is an attribute of God alone, and with this view Christianity attacked the Greek philosophy of antiquity. In Process and Reality (1929:519-530) A. N. Whithead criticized this traditional Christian view. Holding that God is "not before all creation but with all creation," he comments:

> When the Western world accepted Christianity, Caesar conquered; and the received text of Western theology was edited by his lawyers . . . The brief Galilean vision of humility flickered throughout the ages, uncertainly . . . But the deeper idolatry, of the fashioning of God in the image of the Egyptian, Persian, and Roman imperial rulers, was retained. The Church gave unto God the attributes which belonged exclusively to Caesar.

An "imperial ruler" or Lord God, separate from the world, existent before it and superior to it, seems to have remained the matrix of traditional Christian belief. Such a God shaped Newton's concepts, and Whewell's and Kelvin's after him. Although such concepts do not appear in physical formulas, or in the direct description of empirical processes, they are the very stuff of interpretation surrounding fact and formula. In the case of the second law, traditional Christian belief appears to have led, not to the justifiable statement that 'for <u>these</u> sets of phenomena, entropy increases,' but to the enthusiastic generalization that 'for the whole world entropy increases,' and that consequently ". . . all motion except that of heat must have an end, unless it please God to restore by an act of new creative power the dissipation of mechanical effect that always goes on" (Lord Kelvin, quoted from Thompson, Vol. I, 1910:241).

This generalization concerning universal dissipation states afresh the dependence and incompleteness of a world without the immediate presence of the Lord God. It holds our entire modern technology in its grasp, and it must be said, the most primitive superstitions are in accord with its outlook. Why is it that Maxwell's "Demon" is called, against Maxwell's own wishes, a "Demon?" Why, when he could do nothing but aid our technological efficiency, has the "Demon" been met with the "pious hope that for some inscrutable reason no demon would ever be able to crash the gate of our laboratories?" (Bridgman, 1969:5). The second law is today increasingly challenged in the realm of astrophysics. But, where a breakthrough would really count, in the realm of technology, the second law holds as strong a sway as ever, even though it would seem to follow that, if the universal process is self-sustaining, our technology should ultimately be able to make an arbitrarily close approach to such operation.

There is no reason now, nor has there ever been, to take the evidence for the second law as forcing the conclusion that "entropy can either remain constant or increase, but can never decrease." In fact, the evidence adduced in support of the second law may be taken together with Newton's third law of motion -- for every action there is an equal and opposite reaction -- as strongly suggesting the existence of what Whitehead has called "generically different" and counterbalancing phenomena. Yet, there is reason to suppose that this alternative construction is unlikely to be adopted by a science oriented to facts and formula alone. Such an alternative construction requires a gestalt shift of perception, of the type which Thomas Kuhn says underlies most scientific revolutions (1970:123). The present paradigm or overall conceptual model of the universe given by the second law militates against a gestalt switch to another paradigm, at least within the context of "normal science." Kuhn comments (1970:24):

> Closely examined, whether historically or in the contemporary laboratory, that enterprise (of normal science) seems an attempt to force nature into the preformed and relatively inflexible box that the paradigm supplies. No part of the aim of normal science is to call forth new sorts of phenomena; indeed those that will not fit the box are often not seen at all. Nor do scientists normally aim to invent new theories, and they are often intolerant of those invented by others. Instead, normal-scientific research is directed to the articulation of those phenomena and theories that the paradigm already supplies.

It would appear, in light of our growing ecological and energy problems, which have been created by a dissipative technology under the guidance of a dissipative law, that a paradigm switch to an entropy-symmetrical hypothesis would be very desirable. Such a change requires, I think, the aid of philosophy, which alone can provide the critical examination of our underlying assumptions. Such examination involves, not merely the ideas which most immediately determine our technology, but our deepest religious and philosophical beliefs. Lynn White, Jr. (1968:89ff.), has put forth some interesting reflections in this regard. He states:

> The consistency with which scientists during the long formative centuries of Western science said that the task and the reward of the scientist were "to think God's thoughts after him" leads one to believe that this was their real motivation. If so, then modern Western science was cast in a matrix of Christian theology. . . .
>
> As we now recognize, somewhat over a century ago science and technology, hitherto quite separate activities, joined to give mankind powers which, to judge by many of the ecological effects, are out of control. If so, Christianity bears a huge burden of guilt.
>
> I personally doubt that disastrous ecologic backlash can be avoided simply by applying to our problems more science and more technology . . . What we do about ecology depends on our ideas of the man-nature relationship. More science and more technology are not going to get us out of the present ecologic crisis until we find a new religion, or rethink our old one.

As remote from science and technology as it may seem, rethinking our old religious and philosophical concepts may provide the first step towards a new, and better technology. I would like to close with two poems. The first, "Why Wait for Science?" by Robert Frost, gives the culmination of a technology guided by the second law. The other poem, "To the Air of Lorelei," by James Clerk Maxwell, leads in a different direction. Whichever direction we come to take lies, I think, with us.

I

Sarcastic science, she would
   Like to know,
In her complacent ministry of fear,
How we propose to get away from
   Here
When she has made things so we
have to go
Or be wiped out. . . .

--Robert Frost
(E.C. Latham, ed., 1969:210)

II

I (hear) how all nature rejoices,
   And moves with a musical flow.
O! strange! we are lost in delusion,
   Our Ways and doings are wrong,
We are drowning in wilful confusion,
   The notes of that wonderful song.

--J.C. Maxwell
(Campbell, 1882:602)

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VITA

Carter Braxton Finn

Born in Cambridge, Massachusetts, February 14, 1935. Graduated from Berkley Hall Preparatory School in Beverly Hills, California, in 1949, and Seacrest High School, Delray Beach, Florida, in 1953. Graduated from The College of William and Mary in Virginia with an A.B., Economics, in 1964. In September, 1968, the author entered the College of William and Mary as a graduate assistant in the Department of Sociology.