LANGUAGE AND SCIENCE

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Received 26 August 1984, Revised 19 June 1985

Abstract

This is the second article in the series entitled ***Nature: The Supreme Logician.*** *This article discusses various notions associated with the languages of science. In particular, the concept of a rational description, hypotheses, indirect verification, theories, scientific speculation, discipline languages, Mill induction, improper theories, and the notion of a model are discussed. The concepts of falsifiability and hypothesis modification are delineated. One of the major features of our discussion is an introduction to what applied mathematical modelling truly signifies, and an investigation into the unscientific methods, such as absolute randomness, that are ad hocly utilized to reject totally acceptable alternative scientific theories.*

1. Time

Prior to continuing our investigation of the deductive-world—the supermind model—for the development of a natural system, it becomes absolutely necessary to give a technical discussion of certain language concepts and their association with various verbal descriptions for natural system behavior. It is often necessary to incorporate within such descriptions a time notion. We only give a cursory introduction to two possibilities. However, if you have a strong intuitive understanding of the time concept, then this section can be omitted without loss of comprehension.

Since our discussion revolves around the concept of a developing natural system, the term *cosmic time* is useful. A partial description for this concept, as first suggested by H. Weyl in 1923, can be found in many elementary texts in modern cosmology. For example, Bondi defines this notion in the following manner.

> For it is asserted that every fundamental observer sees a changing universe, but that it presents the same aspect to them all, then it must be possible for observer A to find a time t_a according to his clock at which he sees the universe in the same state as observer B sees it at a time t_b by his clock. The universe itself therefore acts as a synchronizing instrument which enables A and B (and hence all observers) to synchronize their clocks.[1]

To apply this to any natural system, we simply replace the word "universe" in this definition with the phrase "natural system."

Cosmic time requires one to believe in certain additional properties associated with developing natural systems, such as the fundamental observer, a uniform substratum and the like. If you are not willing to accept these restrictions, then intuitively we can consider a natural system as a finite entity and that its development "begins" at the moment when it appears in some fixed configuration. In this case, cosmic time can be completely replaced by a universal Feynman diagram[2] concept. We would use the concept of a universal event number (u-number) and u-event intervals in order to analyze system development.[3] Distinct u-event numbers are assigned to distinct events and, hence, become sequentially ordered as are the universal events. The ordering of the u-event numbers need not be considered temporal in character. However, this numbering system does impart the necessary ordering by which we can discuss the development of a natural system in the exact same manner as our forthcoming cosmic time discussion. All one needs to do is to change such expressions as "time t_i" to "u-event number i."

U-event numbers do not require fundamental observers and the like. Futher, the u-event number scheme allows for time *and* space differences to be analyzed rather than restricting such analysis only to cosmic time differences within the development. Since cosmic time is a much less abstruse concept and is well known we retain this terminology thoughout the remainder of this investigation. When the term "time" appears it will from this sentence on refer to cosmic time.

2. Theories

A natural science is concerned with communicating descriptions for the apparent behavior of a named natural system and named system constituents. Suppose that one or more individuals verbally communicate what is claimed to be a consistent and faithful description for the behavior and characteristics of a natural system and the system constituents as such behavior would be observed by assumed human or machine sensors at a moment of time. By introduction of the idea of the color dot matrix, various diagrams, photographs and other visual displays can be faithfully described and, indeed, computer techniques also allow for the systematic mathematical encoding of visual and audio information.[4] Such computer encoded sensorially received "real" information can also be included in the narrative description and retrieved through applicable visual or audio display mechanisms. As is well known the only acceptable description would be one that follows the same logical patterns as can be associated with human thought processes. All other verbal descriptions would be, in general, without comprehensible content. Louis deBroglie states, "... the structure of the material Universe has something in common with the laws that govern the working of the human mind."[5] As Torrance writes, "If the nature of things were not somehow inherently rational they would remain incomprehensible and opaque and indeed we would not be able to emerge into the light of rationality."[6]

Once we have defined a *"rational description* as a logically consistent communicable collection of words, sentences, diagrams, pictures and the like that have been obtained through application of acceptable dialectical, propositional, predicate or other consistent (human) deductive processes,"[7] then we can define a rational description for the regularities presented by a real world phenomenon (i.e. the behavior of what is accepted as a real physical system). The Axiom of Natural Consistency states that "a description for a portion of reality is acceptable if and only if it is a rational description."[8]

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Even though we will discuss other languages, we utilize, for the present, certain nonambiguous procedures and investigate the simplest possible cases in order to give a brief discussion of some of the most salient aspects of *theory* building. Let D be a *discipline dictionary* say for some natural science. This means that D contains all of the meaningful words used throughout this particular scholarly discipline. We further assume that D contains all of the necessary language that is needed to construct an *intuitive first-order language.* Consequently D contains the words, *if, then, and, or, not, only, there, exists, for, all, each,* among others. The construction of the full discipline language L(D) will be based upon a strict grammar that includes all of the usual first-order construction.[9] I point out that many "scientific" statements are written in an intuitive first-order language and, indeed, all specific deductive-world statements are first-order.

The discipline language L(D) includes *propositions, predicates, names for objects* (i.e. constants) so as to allow for the required first-order constructions. For example, if *P* and *Q* represent propositions in L(D), then *"P and Q"* is a member of L(D). If R(x) represents a one-place predicate, then the sentence *"For each x, if R(x), then P"* is a sentence in L(D). If c denotes the phrase "a photon" and R(-) the one placed predicate "- is an elementary particle," then R(-) = *"a photon is an elementary particle"* and R(c) is a member of L(D). Of course, R(c) need not be a sentence that is "true in reality." In what follows L_1 denotes the set of all intuitive first-order sentences contained in L(D). A *general hypothesis* Γ for the generation of a *rational physical theory* (or paradigm) is a consistent subset of L_1. Notationally this is written as $\Gamma \subset L_1$ A *logical consequence deducible from* Γ is a sentence S that is a member of L_1 (notationally $S \varepsilon L_1$) such that S is obtained from Γ by means of the informal rules for predicate deduction (metalogic).[10] For simplicity we often call S *a consequence of* Γ or *a logical implication.* Notationally we let symbols such as Cn represent the usual rules for logical deduction. Cn is often called a *consequence operator* and for this immediate discussion it represents standard predicate deduction. Generally, predicate deduction yields objects that are not the usual "sentences" that appear within scientific descriptions. However, within this entire investigation, the symbol Cn (Γ) will denote the set of all ordinary first-order *sentences* as they are defined within our language L(D).

Technically the set of sentences Cn (Γ) is called a *theory*. There are many different types of "theories." A *descriptive physical theory* is one in which all of the nonlogical and nonuniversal terms utilized within the sentences are assumed to have some physical meaning, if you are a realist.[11] In an informal *mathematical theory* the nonlogical and nonuniversal terms are called *primitive* or *undefined technical* terms and are assumed to have no meaning.[12] In a *formal mathematical theory,* sentences are constructed from strings of "meaningless" symbols. However, in practice Cn (Γ) is not *the* theory meant when a scientist speaks about a "scientific theory." First, most scientific theories are not based upon one set of hypotheses, but are usually based upon a collection (Γ_1, Γ_2, . . . , Γ_n,...} of distinct hypotheses where the theory contains the *subtheories* Cn (Γ_1) ,Cn (Γ_2) , . Cn ,(Γ_n), ... Also it is not necessarily true that a set of hypotheses is a finite set. Some logicians claim that the Theory of General Relativity requires an infinite set of hypotheses. Moreover, scientific theories also contain the rules for experimental and observational inquiry, the rules for the scientific methods to be employed, fragments of mathematical structures, the interpretations of these fragments and even modifications to the logic Cn or the languages. Many so-called scientific theories also contain statements that are entirely outside of L(D)—statements that usually lead to philosophical concepts.

Since we are considering two-valued processes only, then a *verification process for a sentence S* ε Cn(Γ) , is a set of rules, canons, procedures (i.e. empirical, inductive) and the like that yields for S the symbol T or F not both. The symbol T could intuitively mean (2.1) "S is accepted as true in reality with respect to the time interval over which the verification process is conducted" and F would mean the expression "not true" is substituted for "true" in statement (2.1).

The actual hypotheses that are verified are usually not the entire set Γ, but rather a nonempty subset δ of Γ. Indeed, Γ is often highly variable in character. A verification process V_i is distinct from a valuation process for a first-order language since V_i does not apply, in general, to the entire set Γ. As Cohn and Nagel state it, "It is often the case-indeed the most valuable hypotheses of science are of this nature—that a hypothesis [δ] cannot be directly verified."[13] Some of the logically deduced implications of δ that are not contained in δ may be the only sentences that are capable of verification. The process of verifying such hypotheses is termed *indirect verification.*

A basic prototype for indirect verification comes from particle physics. "The existence and properties of the ultimate elements are only to be inferred indirectly from observations of gross matter."[14] Let δ be the hypothesis stated in 1931 by W. Pauli relative to the existence of the neutrino and let $G_1 \subset L_1$ be the necessary hypothesis for Fermi's theory of β decay. Evans writes, "Fermi's theory of β decay, in 1934, developed for the first time a set of measurable consequences of the existence of a neutrino and these have been completely verified experimentally."[15] This process may be symbolized in the following manner. Let Cn denote the logic employed, say first-ordered predicate logic, and Cn(Γ_1) the set of consequences. In general Cn(Γ_1) is an infinite set and a finite set F(Γ_1) $\subset$ Cn(Γ_1) disjoint from δ is what is actually tested. Thus for each S_i ε F(Γ_1) there is a verification process V_i such that $V_i(S_i)$ ε {T,F}. It is a very significant fact that no matter how many implications are verified as T, it is not possible to absolutely prove that neutrinos exist in reality. One of the absolute requirements of the scientific method and the logic employed is that a physical hypothesis that can be indirectly verified only cannot be absolutely demonstrated as "true in reality." It should be known by every individual, scientist or not, that such absolute acceptance or rejection of statements such as δ is a philosophical stance. Paraphrasing Cohn and Nagel,[16] all scientific inquiry that deals with matters of fact and that is based upon indirect evidence is probable in character. The acceptance or rejection of such hypotheses is never beyond every significant doubt. Further, "No hypothesis which states a general proposition can be demonstrated as absolutely true.[17] It is a fact of basic logic that a logical implication of δ can be verified as "true in reality," while each member of δ is "false."[18]

3. Falsifiability

Two other major aspects of theory building—falsification and hypothesis modification—need to be clarified. Falsification is a widely misunderstood concept. Actually the falsifiability associated with any statement in $Cn(\Gamma)$ is totally unrelated to the Cn logical process, but it is related to the verification processes and induction. The scientific method places an additional prerequisite upon the verification process V_i for any $S_i \epsilon Cn(\Gamma)$ that is capable of verification. The process V_i must be applicable to repeated experiments prior to the induction hypothesis. For any given moment of time t the process V_i must be capable of yielding not only a T but also an F when applied to some S_i. For the language L_1 this also means that V_i is capable of yielding a T for the statement "it is not the case that S_i." Thus falsifiability applies to the verification of the implied consequences of a theory and it does not apply to the basic hypothesis δ assuming the theory is only indirectly verifiable. Hence the lack of a falsifiable verification process for some of the implications of an indirectly verifiable theory does not invalidate the hypothesis δ. What it does, obviously, is to lead to fewer verifiable consequences and nothing more serious. On the other hand strict application of the canons of the scientific method would require one to reject δ if no members of $Cn(\delta)$ are falsifiable.

As a classic example of falsification difficulties, assume that δ contains the statements (A) Let t denote the time that exists at the moment you read this sentence. (B) There exists a time x greater than t such that the temperature at all locations within the universe is at least 10^{32} °K. (C) Biological life does not exist when the temperature at any location at which it is placed is 10^{32} °K. Let δ = {A,B,C,}. Define the term "mortal" to mean "there is a moment of time when the biological life of a human being ceases to exist." Adding a few obvious statements to δ we obtain Γ. Let (D) be the statement "Each human is mortal." We assume that (B) and (C) are not directly verifiable even though they may be indirectly verifed as consequences of another set of premises. Let h denote the name for some human being, and M(-) the predicate "- is mortal." Now statement (D) is inductively accepted as true in reality if and only if there is a verification process V_h such that $V_h(M(h))$ = T for each h that is an element of a large finite unbiased sample taken from the set of all human beings. Unfortunately no scientist has devised an experiment or any verification process that yields a T if an individual is immortal. Consequently, at the present time, since no such process is describable within our language, then we must assume that V_h is not falsifiable. However, depending upon what statements we add to Γ there may be numerous sentences in $Cn(\Gamma)$ that have falsifiable verification processes. The fact that (D) is not, at present, falsifiable is no reason to reject Γ. If δ = {D}, then δ still need not be rejected unless we cannot find a falsifiable verification process for any of its consequences.

There are three basic reasons for rejecting, altering or adding to a set of premises Γ. (3.1) There is some $S_i \epsilon Cn(\Gamma)$ such that $V_i(S_i)$ = F. (3.2) There is some $S_j \epsilon L_1$ and a verification process such that $V_j(S_j)$ = T, but S_j is not a member of $Cn(\Gamma)$. (3.3) There are two statements S_i and S_j such that $S_i \epsilon Cn(\Gamma_2)$ but the sentence "S_i and S_j" implies a contradiction. When (3.1) occurs the main set of premises Γ is almost never rejected in its entirety. The Set Γ is often modified so that almost all of the finite set of previously verified consequences is retained, but S_i is not a consequence of the modified Γ. Please observe that since only a finite set of consequences is ever verifiable over any cosmic time interval, then it is almost always the case that the (3.1) situation can occur. We have simply not arrived at the particular S_i that forces this condition.

A vast amount of theoretical effort and huge monetary expenditures are incurred in attempts to correct the situation expressed by (3.2). Usually the premises Γ are consistently extended in some manner to a set Γ^1 (i.e. $\Gamma \subset \Gamma^1$) so that $S_j \epsilon C(\Gamma)$. Scientists search for theories that are more general, that have "greater predictive power." Let $F(\Gamma^1)$ be a finite set of consequences generated by a set of hypothesis Γ, such that each member of $F(\Gamma)$ has been verified and the set contains all statements that are of *interest* to the scientific community. There is a second method to correct the (3.2) situation. A set of premises Γ^1 is sought after such that $F(\Gamma) \subset Cn(\Gamma^1)$ and $S_j \epsilon Cn(\Gamma^1)$. However, it need not be the case that $\Gamma \subset \Gamma^1$.

The final situation (3.3) is the most demanding of these various possibilities. When (3.3) occurs then since we always assume that the set of hypotheses is consistent and that we are following the Axiom of Natural Consistency, then it must follow that one or both of the statements S_i, S_j is not verifiable. However, the logical consistency of the two theories $Cn(\Gamma_1)$ and $Cn(\Gamma_2)$, the requirement for completeness and other considerations tend to demand that (3.3) be corrected. The simplest approach to this problem is to simply reject Γ_1 or Γ_2. This is especially the case if the two finite sets $F(\Gamma_1)$ and $F(\Gamma_2)$ to be verified are equal. The more difficult approach is to modify Γ_1 and Γ_2 in order to obtain $\Gamma_1{}^1$ and $\Gamma_2{}^1$, so that $F(\Gamma_1) \subset Cn(\Gamma_2{}^1)$, $F(\Gamma_2) \subset Cn(\Gamma_2{}^1)$ and either S_i or S_j is not a member of $Cn(\Gamma_1{}^1)$ nor of $Cn(\Gamma_2{}^1)$. Essentially this is what a "unified" set of premises Γ" accomplishes. In general $\Gamma_1{}^1 \subset Cn(\Gamma")$ and $\Gamma_2{}^1 \subset Cn(\Gamma")$. More importantly since Γ" is consistent then the implied contradiction cannot occur as a consequence of $Cn(\Gamma")$.

These articles detail the construction and implied consequences of just such a unifying model. The *deductive-world model* appears to satisfy all of the qualities for a satisfactory unifying alternative that eliminates the various implied contradictions that have appeared recently throughout many other models for system development.

4. Scientific Speculation

The concept of verification is closely related to the expression *scientific speculation* or what was once called metaphysics. As long as we remain within the language L(D) (or better L_1) scientific speculation can be specifically defined. Such speculation always occurs with respect to any Γ where only indirect verification is possible. For disciplines such as quantum theory and cosmology, Frank Wilczek gives us his description for such a mental process:

> ...the explanation of the cosmic asymmetry between matter and antimatter may seem more mythical than scientific. To an extent this is unavoidable, since the extreme conditions of the early universe cannot be reproduced in a laboratory. What distinguishes scientific speculation from myth is its logical consistency and the amenability of at least some of its elements to experimental test.[19]

Notice that Wilczek does not indicate how many verified implications would make the speculative theory accepted fact.

Assuming that we had actual knowledge of the conditions that existed within an "early" universe and that these conditions correspond to such things as a nearly infinite temperature or pressure, then an hypothesis composed of statements describing such conditions is not at present directly verifiable. Wilczek requires verification of *some* of the implications generated by such an hypothesis as it is coupled with descriptions for how natural systems such as electromagnetic radiation behave at the present epoch within our laboratories. Thus it must at least be technically feasible to verify some finite subset of the infinite set of implications produced by such an hypothesis. However, does a speculative theory become any less speculative even if some implications are indeed verified?

The only statements generated by the theory and that can be directly verified are statements that involve macroscopic objects. These include such statements as those that predict the behavior of pointers on gages, counters and differences that exist between those pictures or graphs generated by "received" electromagnetic radiation or assumed particles and those pictures or graphs generated within the laboratory. Indeed, only statements relative to devices that impinge directly upon human sensors are capable of verification.

Even though the deductive-world model is a first-order theory, from this sentence on, we no longer restrict our discussion to a first-order language. However, we do retain Cn as our notation for a logical operator and other concepts such as consistency and the like. Thus we discuss these concepts relative to the set-theoretic logic of Tarski.[20]

For a given theory $Cn(\Gamma)$, let $VS(\Gamma)$ denote *the set of all theory statements that have been directly verified as of the present time.* Let $\Gamma_1, \Gamma_2, \ldots, \Gamma_n$ denote discipline language hypotheses that generate the exact same directly verified statements as those generated by Γ. (Note: these hypotheses may come from different discipline languages.) Notationally this can be written as $VS(\Gamma) = VS(\Gamma_1) = VS(\Gamma_2) = \ldots = VS(\Gamma_n)$. The theories $Cn(\Gamma_i)$, $i = 1, \ldots, n$, are called *alternatives* to the theory Cn(G). If such alternatives exist, then the answer to the above question on speculation is a resounding *no* since the tested set of statements $VS(\Gamma)$ cannot differentiate between these theories. Do such alternative theories exist? The literature is replete with numerous examples of such alternative theories. Let GT denote the General Theory of Relativity. In cosmology we have the steady-state theory which is now able to predict all of the VS(GT).[21] We also have the possibility that classical physics as discussed by Barnes can predict all of the VS(GT) as well as consequences of quantum theory.[22] It has been know for many years that a modified classical Newtonian theory is also capable of predicting all of the VS(GT).[23] In quantum mechanics (QM) we have nonlocal hidden variable theory of Bohm that predicts all of the VS(QM).[24] In quantum measure theory we have the Everett-Wheeler-Graham theory which predicts and improves upon all of the verified quantum measure theory statements. It will be shown in a future article in this series that the theory of subparticles not only generates any verifiable statement associated with the Special Theory of Relativity but generates the entire theory itself. Indeed, the deductive-world theory—the supermind—predicts *all* of the verified statements for *all* scientific theories. (Note that $VS(\Gamma)$ is a subset of the "verifiable" statements.)

Since there are literally hundreds upon hundreds of alternative scientific theories that generate the same verified consequences as some of today's most popular theories, I believe that it is necessary to *technically* define scientific speculation in a narrow sense. For the remainder of this investigation, we use the Logic definition and technically define any statement $S\ \varepsilon\ \Gamma$ as speculation if it is not a member of $VS(\Gamma)$. Clearly this definition may make many modern scientific theories speculation. Notice that if $S\ \varepsilon\ VS(\Gamma)$ and we *assume* that the natural phenomenon being described by the theory $Cn(\Gamma)$ follows the logical patterns generated by Cn, then each member of Cn(S) will be considered as "true in reality." Obviously it becomes more meaningful not to discuss speculative theories, in general, but rather to consider the speculative portion of such theories. Notationally we let $\Gamma - VS(\Gamma) = SP(\Gamma)$ denote the speculative portion of the hypothesis. We call the hypothese Γ *speculation* or $Cn(\Gamma)$ a *speculative theory* etc., if $\Gamma - VS(\Gamma) = SP(\Gamma)$ is nonempty. Of course, if $S\ \varepsilon\ \Gamma$ appears to be only indirectly verifiable, then $Cn(\Gamma)$ is technically *speculation,* at least until this situation can be rectified—if ever.

What is it for indirectly verifiable theories that differentiates scientific speculation from *accepted fact?* With one notable exception the *personal* boundary between speculation and the *acceptance* of a theory as fact is often not an evidence-induction boundary, but rather it is a philosophical boundary dependent upon many personal traits and desires and even language tricks. Such acceptance has no relation to the scientific method. It is ultimately the responsibility of the reader of the various speculative statements generated by a theory to eliminate their speculative nature and to endow them with any degree of "truth" he chooses and for any personal reasons he desires. Notice that accepting an indirectly verified theory as fact is not the same thing as demonstrating by direct verification that each hypothesis is fact. Such theories are usually still (technically) speculation.

There is one unfortunate aspect of speculative theories (the notable exception) that does tend to force a scientist to accept a theory as "fact", at least for a while. If there does not exist an (philosophically?) acceptable alternative Γ^1 such that the set of tested statements is common to $Cn(\Gamma)$ and $Cn(\Gamma^1)$, then for motivational reasons, at least, some individuals insist that $Cn(\Gamma)$ is "absolute fact" even though no such statement as "absolute fact" can be established logically. History is replete with examples where prominent scientists have greatly embarrassed themselves by such an absolute acceptance of a theory as fact only to discover at a later date that certain verifiable implications were proved false or they have simply accepted a theory as fact since for political or philosophic reasons the majority of their colleagues have accepted a popular theory as fact. Even though there are specific rules within the canons of hypothesis and theory building that require a scientist to replace one theory with an alternative theory, there are often great political and economic forces that tend to prevent such a replacement. In today's political atmosphere the major method for alternative rejection is not based upon any scientific canons, but it *is* based upon philosophical or political ridicule. In these articles such methods will not be employed and only the basic canons of the scientific method relative to hypothesis and theory construction are used for acceptance (as a *working model)* or rejection of any speculative theory. When these canons do not allow for such an acceptance or rejection, then the entire matter must be left to an individual's personal and reflective choice. Further, the elementary reasons for the acceptance of an alternative theory or hypothesis such as *simplicity* are relegated to the standard treatises.[25] Our concern in this present article is relative to other insidious and highly significant factors that have in recent times been arbitrarily introduced into theory building in an attempt to destroy the scientific validity of certain well-founded and highly meaningful yet, of course, speculative descriptions.

5. Proper Scientific Speculation

As pointed out in section two of this article ordinary scientific theories are not merely collections of statements written in a first-order language. Scientific theories generally contain an enormous collection of subsidiary descriptions that give the rules and methods that are to be allowed within a specific discipline. In recent times, some very clever and unfortunate "tricks" have been used to improperly limit scientific theory building. We delineate some examples.

With respect to the so-called theory of chemical evolution, we are told by John Farley that modern biologists and biochemists have generally accepted "the evolutionary viewpoint as expressed by Oparin."[26] He makes the following all conclusive statements part of his theory.

> Engles shows that a consistent materialistic philosophy can follow a single path in the attempt to solve the problem of the origin of life. It must have, therefore, resulted from a long evolution of matter, its origin being merely one step on the course of its historical development.[27]

Notice that such words as "only", and "must have" eliminate automatically all other possible theories from consideration. Thus Oparin has built into his "theory" a philosophical bias that is generally not allowed in scientific theory building. Simply recall that only a finite number of statements can be verified over a finite time span and that Oparin's theory of evolution is an inductively established theory. Moreover, as will be shown by means of the deductive-world model, there is an absolute alternative to the theory of the universal uniformity of nature (uniformitarianism) that immediately proves that those portions of uniformitarianism necessary for his theory are unverifiable (as should be obvious).

Harlow Shapley stated in 1961 that various theories for the sudden appearance of life forms are "irrational."[28] Once again an eminent scientist has interjected an unfounded word "irrational" into his theory of evolution. This clearly eliminates all such theories that imply such types of "sudden appearance."

We discussed in the first article in this series[29] how Bohr attempted to inject into the language of quantum theory an additional statement that automatically limited the languages that one can employ to investigate the microphysical world. It has been established that his attempt actually would yield an inconsistent quantum theory. However, it did have the effect, over a long period of time, of inhibiting scientific knowledge by preventing a deeper rational analysis of this invisible world.

In the very important article "The Evolution of the Universe", G. Gamow writes the following as his very first sentence.

> The discovery of the red shift in the spectra of distant stellar galaxies revealed the important fact that our universe is in the state of uniform expansion, and raised an interesting question as to whether the present features of the universe could be understood as the result of its evolutionary development, which must have started a few thousand million years ago from a homogeneous state of extremely high density and temperature.[30]

Notice that Gamow uses the word "fact" as well as "must" within his brief "scientific" description. Once again we have a "theory" that in its grammatical construction has introduced word-forms that automatically eliminate any alternative description. We further note that it is very common for Soviet-trained scientists to utilize these unfortunate language techniques.

All of the above examples illustrate how theories that claim to be "scientific" can be so constructed that they violate the rules for speculative theory writing. In order to avoid logical or linguistic errors, and to maintain the integrity of the scientific method it is strongly advised that individuals adhere to following two rules whenever they present their deduced conclusions. (4.1) No statement can be deduced from the hypothesis that specifically requires the rejection of any other rationally presented theory. (4.2) The rejection criteria for any scientific theory $Cn(\Gamma)$ must be based upon *general rules and procedures* that apply to *all* theories and these criteria must be stated in a metalanguage that is exterior to the language of the theory. (Note: these rules are obtained by intuitively applying the theory of logical types.) For above reasons the theories as presented by Bohr, Oparin, Shapley, Gamow and literally thousands of our modern day scientists such as Sagan are not scientific theories, but are scientific descriptions coupled with philosophic generalizations.

There are, of course, many terminological methods that yield proper word-forms while retaining a theory's speculative content. Changing such phrases as "important fact" to "important possibility" is but one example. However, the best approach seems to be the modern trend of utilizing the term "model" - a term that will be shortly but briefly discussed. Thus one could write that "within our model such and such occurs." Some individuals claim that "all scientists know that these are but speculative theories." Unfortunately they have not taught these facts to our children nor expressed them to the general public.

Two other greatly misunderstood terms have appeared throughout the scientific literature and especially in the popularizing books, movies and television. These terms are *chance* and *randomness*. For a relatively deep analysis I refer you to the Bohm's treatise,[31] especially Chapter II, sections 11-14. In this article we touch upon the language aspects of these concepts. Even though these terms are concepts and as such would probably have more "meaning" than is finitely describable within any language,[32] we examine a restricted, but practical view, the "operational" content of these two concepts.

First, it is proper to utilize these terms within a scientific theory, *if* the reader understands that their meaning is *relative*. This fact is amply demonstrated by Bohm when he introduces the notion of levels of "chance contingencies." These terms are related operationally to descriptions for "predictions" and for "causes." Within a theory language a ***one-to-many causal statement*** is a description of how a *describable causal process*, as discussed in the first article in this series,[33] produces many (possibly infinitely many) describable events. Using a list of theory statements that has been accepted as general descriptions for systematic behavior (i.e. relations) between events, a set of such events is termed "statistically random" if it is accepted that they do not exhibit any of the listed systematic behaviors. Note that this does not mean that we cannot have statements that describe the behavior of aggregates. If using another list of theory statements describing causal processes, it is accepted that there is no causal statement within the list that has produced such a set of statistically random events, then the set of events is said to have been produced by a "random cause." There are many one-to-many causal statements that yield, in the above operational sense, sets of events that appear to be statistically random. For example, the phenomenon of Brownian motion has causal statements. One simply describes the entire experimental set up that yields this behavior and attributes the phenomenon to the effects of molecular motion and collisions.

Essentially, Bohm argues that random causes or statisical randomness is theory and, hence, language dependent and that in an extension of the theory a cause might be described, or predictive or systematic statements supplied. We will expand slightly upon Bohm's argument. Assume that an experiment leads to two mutually exclusive and describable events X and Y. Now there seems to be no acceptable statement within our theory that allows us to describe a systematic relation between these events. In order to "establish" that this might be the case we repeat the experiment a large number of times recording whether or not event X and Y occurs. Statistical tests lead us to accept that the events are binomial with probability of 0.5.

Mark Kac[34] has once again shown, what was once a well-known fact, that no matter what tests for statistical randomness are applied to the sequence of X and Y events that the exact same tests applied to a *determinate* sequence of X and Y events that is generated by taking the fractional part of the numbers expressed by the sequence $2^n x$, for an appropriate x, will "establish" that this systematically generated sequence of X and Y events is also binomial with probability of 0.5. What this signifies is that *if* a physical process is modelled by this determinate numerical process within an extended theory, then even though the events are predictable and thus highly systematic they will appear operationally within our original theory to be statistically random. In the next article in this series, where we discuss the concept of the "developmental paradigm", it will be proved that *any* description utilizing a "natural" scientific language for a sequence of observed events is not produced by a random cause and that the events are not statistically random when viewed from the extended theory we call the deductive-world model. Even though this last statement may appear difficult to comprehend, it displays properties of the mathematically generated supermind processes and certainly indicates how different these processes are from our own reflective methods.

In a large number of theories the philosophical concept of *absolute statistical randomness* or *absolute random causes* is incorrectly introduced. What this means is that there is no systematic behavior, describable or not, between the events or no causal process, describable or not, for their production, respectively. What the introduction of these two absolute concepts does is to once again limit the languages that the scientist can use to discuss alternative theories. Consequently, properly stated scientific theories can employ these concepts of randomness within the theory language, but they cannot utilize the philosophically based concepts of absolute randomness.

6. Uniformity of Nature

As first pointed out in 1843 by the codifier of the scientific method—John Mill—there is an underlying assumption that permeates all of our scientific investigations. In order to apply the basic principle of induction some doctrine of the "uniformity of nature" must be *presupposed.* As Mill states this doctrine, "there are such things in nature as parallel cases, that what happens once, will, under a sufficient degree of similarity of circumstances, happen again."[35] Mill also stated, however, that the principle should not be applied except in a spacially local sense. Mill's induction only allows for full generalization in the time coordinate. Indeed, this requirement for Mill's induction is with respect to cosmic time. Mill's induction can be modelled as follows: let $S_i \in Cn(\Gamma)$ and V_i be a verification process for S_i. Over a space-time interval $S \times C$ where:

(6.1) $S = \{(x, y, z) | \ a \leq x \leq b, c \leq y \leq d, f \leq z \leq h\}$ and $C = \{t \mid t_1 \leq t \leq t_2\}$, $a \neq b$, $c \neq d$, $f \neq h$, $t_1 \neq t_2$ and $a, b, c, d, f, h, t_1, t_2$ are real numbers,

individuals replicate the verification process V_1 for finitely many ordered triples in S and for a finite increasing sequence of cosmic time $t_1 < t_2 < \ldots < t_n$. If for these n distinct space-time points $V_i(S_i) = T$, then Mill induction generalizes over $S \times C^1$, where C^1 is all of cosmic time. This type of generalization then assumes that due to the "uniformity of nature" $V_i(S_i) = T$ for each $(x,y,z,t) \in S \times C^1$. Consequently, we do have a restricted form for the doctrine of the uniformity of nature. Certain *apparently* time and space independent natural science statements or statements that include an explicit space-time alteration process are singled out by this induction process and are called "first principles" or "laws of nature." These so-called laws of nature are, of course, only humanly constructed descriptions for humanly comprehensible phenomena.

With regard to the uniformity of nature, modern science often takes yet another leap of faith and extends the induction-generalization process not just to all of cosmic time but to all of space as well. This is the pure assumption of the *universal uniformity of nature* (uniformitarianism) — an unstated assumption made by many of the individuals that deal with long term developing natural systems. Such systems occur in astronomy, cosmology, micro and macro evolution, anthropology, among many others. It is self-evident that to have a natural science one needs to assume a local doctrine of the uniformity of nature where we generalize over $S \times C$ only. Later in this series of articles, it will be shown analytically, that no doctrine on the uniformity of nature is directly or indirectly verifiable. The doctrine is not even speculation in our restricted sense. Such a doctrine must be accepted purely on "faith" as an *a priori* principle. In these articles, only local uniformity employing a natural science language, will be accepted; but, notice that this is a weaker (unverifiable) principle since both the universal and Mill uniformity of nature imply local uniformity but *not* conversely.

7. A Major Controversy

We are now able to analytically expose one of today's major controversies relative to scientific theories. Let Cn(T) be a theistic theory based upon certain theistic hypotheses T. A proper speculative scientific theory Cn(Γ) when combined with Cn(T) (which we notationally write as Cn(G) ∪ Cn(T)) can lead to an *inconsistent* collection of statements. Usually this occurs, when a statement S ε Cn(Γ) is the negative of a statement S_1 ε Cn(T). This yields the contradiction "S_1 and not S_1." There are certain theories that have been termed as "creation science" theories that when combined with certain theistic theories *do not* lead to a contradiction, while many of the improperly stated scientific theories not only eliminate alternative theories improperly but also yield contradictions when combined with specific or, indeed, any theistic theory. A properly constituted speculative "creation science" theory Cn(Γ) may not only yield the exact same verified statements of some popular theory Cn(P), that contradicts a theistic theory Cn(T), but Cn(Γ) may also yield all of the popular theories, verifiable statements. Moreover, it is certainly possible that the set VS(Γ) contains more verified statements than the set VS(P), in which case Cn(Γ) would meet one of the important criteria for theory acceptance.

Thus even though Cn(Γ) may be more technically acceptable as a working model than is Cn(P) your actual acceptance or rejection is purely a personal and experimental or philosophical matter. Unless we exist in an absolute scientific dictatorship then there can be no rational scientific reason for not allowing individuals upon personal reflection to decide for themselves whether or not to accept Cn(Γ) , at least as a working model. The fact that it does not contradict some theistic hypothesis T, exterior to Cn(Γ) , is not relative to the theory's scientific merit. The only obvious reasons for refusing to present Cn(Γ) as a viable theory is an attempt to restrict both financially and educationally all speculative theories to those that *do* contradict certain theistic concepts since these noncontradictory creation science theories would tend to yield indirect proof for the theistic theories. I shall leave it to the reader's imagination as to a possible source of this most irrational trend.

Further, there is one more interesting aspect of this controversy. Many theistic theories contain portions of the language used in the natural sciences. It may be the case that many statements within Cn(Γ) correspond exactly to the natural science statements in Cn(T) including all of the verifiable Cn(T) statements. Since we are assuming that both Cn(Γ) and Cn(T) are speculative theories then this may appear to *force one* to accept Cn(T) as well as Cn(Γ) . That this is not the case should be self-evident. In my personal opinion individuals should spend a great amount of effort in study and contemplation, and bring to bear their personal experiences and, indeed, actual physical manifestations before they reject or accept something that is so vastly important as a theistic theory. It is the responsibility of scientists not to influence an individual's efforts by interjecting false scientific claims, and not to utilize the erroneous methods that are outlined within this article.

8. Model

The term "model" is extensively used throughout the scientific literature in a variety of contexts. We have such concepts as *the physical model*, *the analogue model*, *the conceptual model*, *concrete models*, *mathematical models*, *abstract models*, and many others. In a previous article, which the reader may wish to consult, I discuss the ideas of the analogue and conceptual models in some depth[36] and will not do so within this discussion. Further, the mathematical concepts of the concrete and abstract model have little relation to our present investigation.

A *physical model* was originally conceived of as any actual construction, picture, drawing, diagram or written description employing physically meaningful constructions, objects, terms, and the like that only *represented* or *mirrored the behavior* of another distinctly different and sometimes unknown natural system. It is significant to note that the physical model is a *concept* and as such includes within its "meaning" many unindicated deductions that depend strongly upon an individual's experience, knowledge and intuition. The concept that the model is attempting to convey is much deeper than the mere representation itself, if the viewer has an appropriate amount of experience.

Originally the most important aspect of model construction was the fact that it only represented the behavior of some other physical concept. It was not assumed to correlate in meaning directly to the objects being represented. As a prototype simply consider the Newtonian gas cloud that is often used as a model for the expanding universe.[37] Each element of the gas is representative of an entire galaxy of stars. However, for many physical models this is not how they are now perceived. They have lost their purely behavioral content and have taken on the more specific meaning of a speculative theory. That is to say that the constructions, pictures, diagrams and written terms are now assumed to correlate directly to "real" objects, events or phenomena, where these methods only mirrored behavior originally. As a prototype of this contextual change we consider the "quark model."

As of 1969, the quark model had progressed from a purely mathematical context within group theory to a very weak physical model. "In the quark model quarks are not viewed as mere mathematical objects but as capable of somehow being realized in nature. We do not know how."[38] As of 1980, through a vast amount of imaginary and expensive effort the model had changed its character into a full speculative theory.[39] Since that time the realists have taken over and we are now told that ". . . the reality of quarks as the *fundamental* constituents of hadronic matter has been established beyond doubt."[40]

As we have previously pointed out since this is an indirectly verifiable theory only, then this last statement is untrue. Moreover, as will be established in the next article in this series, an alternative theory rationally displays a more fundamental character of hadronic matter and, indeed, all matter. There is a portion of the descriptive deductive-world model termed the "supermind" portion that can generate deterministically all of the macroscopic effects predicted by the quark model. A deeper analysis rationally shows that within this submodel there are objects called "superworlds" that are part of the D-world mechanism for such a generation. However, when the superworlds are analyzed it is discovered that they contain objects that can be *generally* modeled by various humanly comprehensible processes but that there can be *no* humanly comprehensible models of any type that could allow for any *specific* knowledge as to either their content or the mechanisms by which these objects came into being. These facts can be extended to show that there also must be an absolute lack of some humanly comprehensible information as to how any fundamental material system is produced. On the other hand, such information is not lacking within the D-world.

From the above discussion, it should be self-evident that physical models often become *extended* physical theories. However, a certain portion of such theories is usually not specifically expressed in some written form but, as it is claimed, is within the imagination of the viewer, who through education and experience has developed a special intuition that allows for conclusions being deduced without the need for an *immediately clear* rational argument.

Finally, as with the quark model, it often occurs that individuals become so overwhelmed by the predictability of their speculative model that for some personal or philosophical reason they now claim that what was only designed to mirror behavior and have no other relation to reality is now a "true and faithful" representation for reality. I do not hold that such philosophical procedures are incorrect, only that they should be specifically identified as such.

It is unfortunate, but a verifiable fact, that many of today's most outspoken scientists do not have even the most rudimentary knowledge of how mathematics is applied to various scientific disciplines. This is especially the case when applied mathematical modeling is discussed. For this reason it is absolutely necessary that I give a brief yet accurate overview of these general procedures as illustrated by two significant prototypes.

First and foremost I cannot emphasize strongly enough that an (applied) *strong mathematical model* for the basic logical workings of a discipline theory is NOT an abstract mathematical object. Such strong models should always be based upon well established experimentally verified or self-evident statements dealing with real and actual events.

Quantum theory has such a strong mathematical model. The actual and real events are the methods and difficulties actually observed in measuring various properties of the macrophysical world. It is observed that the processes by which human beings are forced to measure particular macroscopic properties will alter some of these macroscopic properties and even alter the measuring apparatus itself. Under certain circumstances, no alteration appears to take place in the property being measured during the measuring process. These observations are then impressed upon the microphysical world and lead to the *law of simple observation*. Other observed requirements for human measurement lead to the *law of complex observation* and the concept of *compatible* and *incompatible* observations. These may not be general laws of nature, but they are laws of *human* nature and the processes by which human beings measure quantities. These "laws" are expressible in a discipline language L_1 first and not in a mathematical formalism.

Now it is discovered through a simple first-order discipline language argument (not a mathematical argument) that the law of simple observation behaves exactly like an "idempotent operator." If this law is abbreviated by a single symbol Y, then this observation can be expressed in the form $Y^2 = Y$. If this same abbreviation process is applied to the law of complex observation, compatible and incompatible observations, then it is discovered that in abbreviated form these laws behave like mathematical operators.

The term "idempotent operator" is an abstract mathematical notation that utilizes a mathematical discipline language and is probably not, as yet, a member of L_1. From this brief discussion it certainly appears possible to *correspond* these laws of observation to objects within an abstract mathematical structure. The structure selected is called a *separable Hilbert space* and has its own discipline language—its technical language. Other correspondences are made between terms in L_1 or more likely terms added to L_1 and this structure. The expression "state" corresponds to a vector or operator. By this approach a strong mathematical model is constructed in such a manner that numerous expressions in the discipline language correspond to what were abstract objects within the mathematical theory. Moreover, there are also techniques for incorporating the actual numerical measurements that one can probably expect from such observations within this strong mathematical model. It is especially important to realize that with respect to such strong mathematical models, many of the abstract terms within the mathematical theory are not utilized but are replaced by concrete and specific expressions within L_1. On the other hand, some of the abstract terms may be included within L_1 especially if they are common to both L_1 and the mathematical language. For example, the abstract terms vector, line, path, point, surface and the like now become concrete expressions within L_1. Sometimes you only know that you are working within the abstract structure or the strong model by the context.

> It is not the purpose of this article to discuss the torturous, exhausting and, yet highly creative back-and-forth methods that produce this correspondence that logically links the discipline language physical description with such a mathematical structure.[41]

Simply notice that including the laws of measurement within a theory $Cn(\Gamma)$ we have now made a fragment of a mathematical theory $M_1 \subset Cn(\Gamma)$. It is a basic property of human deduction that $Cn(M_1) \subset Cn(\Gamma)$. Now the theory $Cn(M_1)$ may not generate any significant concepts. For example, simply because we have sums of "state" vectors does not mean that we have introduced enough of the mathematical structure in order to discuss convergence. Thus the model constructor adds other simple mathematical concepts to M_1 in order to yield a meaningful theory. Unfortunately it is often the case that if M is an extension of M_1 (or even the same as M_1), then $Cn(M) \not\subset Cn(\Gamma)$. Two methods are utilized to "correct" this situation. The first method uses a restriction technique where only a certain $A \subset Cn(M)$ is used as a "mathematical basis" for $Cn(\Gamma)$ (i.e. $A \subset Cn(\Gamma)$) .For example, rejecting "on physical grounds" certain negative measures that are generated by differential equation models. On the other hand, Cn(M) is often made into a translated subset of the discipline theory in the obvious manner by assuming that all terms in Cn(M) are related to discipline language expressions. Moreover it is always necessary to let some terms or expressions in Cn(M) correlate to actual observable phenomena or empirical operations. For the purposes of this second method certain statements are often added to $Cn(\Gamma)$ in order to "interpret" many members of Cn(M) that were not previously assigned a physical language term. Coupled with these two methods we have the fact that a vast amount of the actual logical arguments that yield members of $Cn(\Gamma)$ from finite subsets of Cn(Γ) do not use members of Cn(M) at all. Thus even though it is claimed that such theories as Cn(Γ) are "mathematical" in character and, hence, the logical conclusions follow the most rigorous procedure known to the human being, in actuality this is not the case. The arguments are based upon members of Cn(Γ) - Cn(M). It is because of the actual methods used to argue for certain conclusions that many of these "mathematical based" physical theories or models generate controversy and paradoxes. Some of these controversies will be examined in later articles. Of course, we are always left with a basic question. Do these interpretations correspond to reality or are they simply imaginary concepts that aid human comprehension?

The process utilized to construct the deductive-world model (i.e. the D-world model or NSP-world model) is entirely similar to the methods used to construct all such mathematically based models as outlined above except that the model is based directly upon real and actual properties that have been observed trillions upon trillions of times for at least 2300 years and is more strongly related to a discipline language than other theories. The discipline theory is the theory of how human beings must communicate their ideas. The discipline theory is called Logic and portions of it were apparently first formulated by Aristotle who also apparently described the concept of the developing natural system.[42] It is evident that all scientists must follow the specific rules required for such logical communication.

In 1847, G. Boole discovered that some of the rules for logical communication correspond to a mathematical structure that we now call a Boolean ring. With this discovery the formal discipline of *mathematical logic* was born.[43] The same type of terminology exchange is made between the objects in Logic and the abstract mathematical entities. For example, in one portion of the D-world construction a single English word corresponds to a "finite equivalence class of partial sequences of natural numbers" and other portions of a mathematical structure called a superstructure correspond to logical operators — the logical rules all human beings must apply to be classified as "rational." Other portions of the D-world model correspond to the 2200 year old mental process known as *infinitesimal reasoning*[44] and since the back-and-forth modelling process is still continuing at this writing other future correspondences should be expected. Consequently, the D-world model is a strong mathematical model and, as such, a portion predicts these real describable mental processes that have been continually observed and discussed at least since Aristotle. The interpretations are such that contradictions do not occur, assuming that the mathematics is consistent, since many of the defined concepts are defined by the mathematics itself. It uses a discipline theory language and is, thus, a concrete rational extension of our most common everyday experience. In the next article in this series we investigate the "logic behind" the development of a natural system and specifically show that this logic is operationally obtained from the supermind portion of the deductive-world model.

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MINUTES OF 1985 BOARD OF DIRECTORS MEETING

A meeting of the Executive Committee was held Thursday evening at Howard Johnson's Motor Lodge, Ann Arbor, Michigan. On Friday, 12 April, between the hours of 0800 and 1600, the Research, Quarterly, Publishing, Constitution and Financial Committees held meetings, each lasting about two hours. In each committee an appointed secretary recorded the discussions in preparation for the Saturday plenary session.

The official annual meeting of the board was opened at 1900 hours by President Rusch in Room 102 of the Science Building at Concordia College, Ann Arbor, Michigan. Present: D. Boylan, W. Frair, G. Howe, D. Kaufmann, R. Korthals, J. Meyer, G. Mulfinger, W. Rusch, N. Smith, E. Williams, G. Wolfrom. Absent: H. Armstrong (deceased), C. Burdick, D. Gish, J. Klotz, J. Moore, H. Slusher, P. Zimmerman. Also present were 18 visitors. The president welcomed everybody to this the beginning of the twenty-second year of the Creation Research Society; and he called for silent prayer, particularly requesting that the Armstrong family be remembered.

The president introduced Dr. David Schmiel, president of the host college. Dr. Schmiel expressed a welcome and then talked about the program of Concordia College, particularly their training of students.

Minutes of the 1984 Board of Directors meeting were read. The secretary reported that the following had been elected for a three-year term on the board: John W. Klotz, Richard G. Korthals, Wilbert H. Rusch, Harold S. Slusher, E. Norbert Smith, Glen W. Wolfrom. The election report was accepted.

The treasurer's report from Korthals indicated that the 1984-1985 total income was $69,938.90 and total expenditures $53,826.49. Total cash assets of the Society equal $149,127.64. The laboratory fund has increased from $116,568.09 to $137,454.92. During the past year those who received life memberships paid $3,250 into the special endowment fund. This was Korthal's last treasurer's report because he is retiring after 16 years of faithful service in this office.

President Rusch, who was treasurer from 1963-1969 and has been membership secretary from 1963 to the present, introduced Glen Wolfrom as the new membership secretary. Then Rusch indicated that the total memberships and subscriptions were down by about 130 from last year.

Vice-president Howe was introduced and he reported that the new Research Committee chairman is John Meyer. He and Meyer spent time during the summer of 1984 at the Grand Canyon Experiment Station (G.C.E.S.). They fenced the property and laid out 5-meter-square quadrats in preparation for a systematic study of the biota. He reported that the cost for drilling the 80-foot well was $1,200. There appears to be 40 feet of water, and plastic piping has been used. Then Meyer gave a slide-illustrated presentation regarding the desert pupfish (*Cyprinodon)* and the tassel-eared (Kaibab) squirrel, *Sciurus aberti.* Williams gave details regarding a Grand Canyon Hakatai shale sample which had been treated for examination with the electron microscope, particularly to check for the presence of pollen grains. Research with the shale is continuing. There were a number of questions from the audience.

The president expressed the gratitude of the C.R.S. to Mr. David Golisch and others who were visiting from the Southeastern Michigan Creation Science Association (formerly the Detroit Creation Science Association). Mr. Golisch then spoke briefly to the audience expressing his appreciation for the work of the C.R.S. The meeting was adjourned at 2030 hours for refreshments provided by the Creation Science Association.

The meeting was reconvened at 2045. Mulfinger gave a report about C.R.S. books indicating that the following sales were made during 1984-1985: *Why Not Creation?,* 73; *Variation and Fixity in Nature,* 106; *Thermodynamics and the Development of Order,* 134; *The Moon,* 11; *Decade of Creation Research,* 3; *Time Upside Down,* 24; *Design and Origins in Astronomy,* 290; *The Argument,* 95. In this year the money taken in from the sale of books doubled from last year; and it is hoped that at this rate book sales will produce an increased income which will be above costs. Publication of some other monographs is anticipated.

Then Williams gave a tribute to past Editor Armstrong for his service to the Society. Williams indicated that the past year's quarterly, volume 21, contained 216 pages, which is a slight reduction from last year. There have been a number of invited papers. Norbert Smith will be taking over the "Panorama"; and John Moore has been writing the Education Column, which is expected to appeal to teachers. These two features should be of particular general interest in addition to the more scholarly papers. The content of volume 21 was divided as follows:

	Pages	Percent (%)
Biological Science	34.5	16.0
Physical Science	36.5	16.9
Earth Science	62.0	28.7
Philosophy of Science	10.5	4.9
Biography	15.5	7.2
Book reviews	16.5	7.6
Cover, Ads, CRS business	32.0	14.8
Quotes	8.5	3.9