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A Study in the Use of the Question: An Autodidactic Aid

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A STUDY IN THE USE OF THE QUESTION:
AN AUTODIDACTIC AID

by

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VITA

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CHAPTER I

THE PROBLEM

The application of some or other form of interrogation to the problems of education goes back at least as far as Socratic dialectic as seen in the Platonic dialogues. The use of questions as a part of the educative process seems to have taken place more or less continuously from at least that far back down to the present time. Perhaps the most common use of questioning in education has been evaluative. But, as in the case of Socratic dialectic, some kind of questioning has frequently been seen as an integral part of the learning process rather than as merely an evaluative tool. It is probable that one of the basic assumptions that has served to justify this use of questioning is the belief that questioning tends to promote both faster and more permanent learning by stimulating greater and more vigorous participation of the learner in the process. This belief constitutes the basic premise of the present work.

The problem addressed in this work is the formulation of an educational approach to a document in the philosophy of science that will be largely auto-didactic in its application. The fact that some of immediacy of an in-person, face to face dialogue are sacrificed by the use of a written format is counterbalanced by at least one advantage that the spoken format fails to provide. This advantage is the availability that the written format can supply. Thus, this effort represents an attempt to combine some of interactive stimulation of dialogue with the availability of the written format.

The task attempted here, then, is to start with a document, i. e., a professional paper, in the philosophy of science and derive from it a set of questions which will serve as an autodidactic tool that will facilitate the learning of that document. The primary problem lies in the analysis of the document that is required to convert all of its significant concepts into questions in such a manner that the complete set will reflect the conceptual patterns of the document.

The level of profundity that this effort will attempt to attain is the middle level. That is, there will be no attempt to construct the questions in such a way that they will teach the fundamental concepts that a student must have become acquainted with before having begun the study of the document. Neither will an attempt be made to teach the student the higher skills that will enable him to synthesize new concepts by rearranging the juxtapositions of the elements of the concepts that can be learned from the study of this document, to evaluate these concepts through the use of external criteria, nor to relate these concepts to external conceptual contexts. The task attempted here is rather to develop a set of questions that will enable the student to understand the concepts as they are expounded within the document itself.

The problem of ordering and categorizing the questions logically is addressed to some extent here, but not that of ordering with reference to didactic considerations. It is, of course, possible that the logical order will turn out to be the optimal didactic order. While the close association that has developed in people's minds over the years linking the concepts of logic, thinking and learning tends to lead to the conclusion that this sometimes assumed coincidence is a fact, the truth is that this cannot be safely taken for granted. Moreover, the undertaking of the empirical investigations that might serve to establish or refute this principle is beyond the scope of this work.

One relatively peripheral assumption that has to some extent guided the form that the results of the present inquiry have taken is the principle that emphasizes the importance of establishing and strengthening associations, making connections, between the elements of the concepts being studied. A palpable result of the application of this principle to the formulation of the question-answer set that constitutes the concrete product of this work lies in the fact that the suggested answers that have been suggested for these questions invariably include the whole sense of the questions within themselves. It is the above named principle that justifies this apparent redundancy.

In sum, what is attempted here can be conceptually divided into two main categories of tasks: (1) to analyze the conceptual structure of a document in the philosophy of science, and (2) to categorize the results of this analysis in a such a way that the results can be used to guide the formulation of a group of questions that somehow manages to express or reflect that structure. The next chapter will consist of a discussion of some of the details of the nuts and bolts methodology that structures the tasks whose aims have just been stated.

CHAPTER II

THE METHOD

What will be attempted here are three tasks: (1) to give a brief account of the document to be analyzed, (2) to describe briefly the process that led from an analysis of the document to the final result, and (3) to explain the method of relating the final result to the process that produced it. The first of these tasks will now be performed.

The document to be used as the sample test to be "taught" by the method proposed here is Chapter 5, "Concepts of Model", of Mario Bunge's work, Method, Model and Matter.

It is a work in the philosophy of science dealing with the use of models in science. The role of models in science has, over the years, motivated an ongoing controversy in the philosophy of science. The question that asks, "To what extent should models be considered as part of scientific theories or to what extent should they even be accorded an integral role in an account of the web of interrelated processes that constitute the body of scientific endeavor?", forms one aspect of this controversy. The problem of defining the limits of the concept of "model" forms another. The document under consideration here addresses itself primarily to the second of these two problems, dealing with it as indicated in the following sketch.

The work concerns itself primarily with four basic concepts: referent, model object, theoretical model, and general theory. (These concepts will be hereafter be referred to as content-concepts.) Referents are real objects, processes or situations that are to be represented as the first step in the process of accounting for them. Model objects are qualitive representations of referents. They consist of lists of their significant elements or properties, possibly in conjunction with some information about their spatial disposition, but they lack any important quantitative data about the ways that these elements or properties interrelate. Theoretical models are the result of supplying model objects with the quantitative data that they lack. Theoretical models consist of series of logically interrelated statements that quantitatively relate the elements and properties of the model object to each other. They are also called specific theories. General theories are mathematical statements that may have a wide range of specific applications that can be implemented only indirectly by being combined with model objects to form theoretical models.

That they can be tested only in this way points up the importance of theoretical models and, hence, of model objects.

The primary polemical thrust of this text relates to the proposition that model objects (and, by extension, theoretical models) can be classified as black box, grey box, translucid or transparent boxes according to whether they supply none, some, or much information about the inner workings of their referents. Black boxes give only the input and output of the system, while successively lighter colored boxes connect the input and output by providing successively greater amounts of information about the mechanism of the system. The text, then, opposes the rather behavioristic viewpoint that maintains that the black box is enough. This viewpoint contradicts the main philosophical position of the text by implying that, since no mechanism has to be explained, none exists. The text, then, reflects the view that a mechanism must be assumed, and, in cases where scientific knowledge is sought, an attempt must be made to explain it. This ends the implementation of the first of the three specified tasks: to examine briefly the document to be used in this work as a sample object to be learned. Now the second task, the description of the derivation of the results from the document will be attempted.

The approach to the studying of such a document herein proposed assumes that a set of questions and answers can reflect the results both of a logical analysis of a text and of the method that is employed to transform that analysis into the set of questions and answers. The philosophical implications of this assumption will not be questioned in the present work, since its use here will be primarily practical. Neither will the present task include the actual doing of the analysis. Rather what will be attempted is merely to provide a description of the general processes that figured in the task of the analysis that resulted in the production of the set of questions and answers. The first of these processes is the separation of the task of analysis into two principal divisions: (1) the discovery of ways of categorizing the textual material itself and (2) the invention or discovery of ways of categorizing the kinds of tasks that the resultant questions will represent.

The first of these divisions, the problem of categorizing the textual material, is also divided into two subproblems: (1) the problem of classifying the specific ideas that are to be found in the text and (2) the problem of finding more general categories to implement the classification of the kinds of ways that the author has chosen to deal with those ideas that are specific to the text.

The ideas or constructs that are specific and to a considerable degree peculiar to the text are those (as explained above) of referent, model object, theoretical model and general theory (content-concepts). An examination of the text shows that every statement or idea therein can ultimately be traced back to one or more of these content-concepts.

Accordingly, the analysis proceeded by means of an minute examination of the text. The purpose of this examination is to sift out and list all of the statements, claims and comments in the text and then to divide them into subsets according to which of the four concepts predominates in each. These statements, claims and comments, then, within the framework of the task being attempted here, constitute the logical elements of the text, elements which had at this point had been categorized and labelled according to one criterion: their primary conceptual focus. The results of this first categorization are the content-concepts.

After isolating and labeling the logical elements of the text according to one criterion, it became necessary to repeat the task using another criterion in order to implement the second part of the first task: the categorization of the means that the author chooses to deal with the content-concepts that he has set forth. This does not mean that the already obtained categories were subdivided, but that the complete list of logical elements was repartitioned without regard for their first division. This procedure was necessary because the textual examination revealed that the author did not deal with each given content concept in its own way, inventing or applying means that are especially appropriate to each. Had this been the case, each mean-category could reasonably have been designated one of a number of subcategories of each content-concept. What he did do, rather, was to select from a field of means-categories the ones to be applied to each content-concept in way that turned out to be unpredictable solely on the basis of the identity of the latter. Thus, a set of means-categories was applied to the raw list of content--concepts leaving each element twice categorized--a member of two separate categories. Yet neither of these categories bore any simply expressed relation to the other. The foregoing consequently comprised the two stages of the first of the processes that were performed for the purpose of deriving a set of questions and answers that would reflect the logical structure of the text.

The next procedure that was performed for this purpose dealt not directly with the text per se, but with the text only indirectly by means of processes that would contribute to the formulation of the questions that would be derived from it. The first of these processes was the selection of a series of modes in which to formulate the proposed questions, to answer questions about whether the questions would require the user directly to supply an answer, to choose between a number of given answers or to come up with an answer by means of deduction. This procedure did not, like the previous ones, result in a new set of categories to apply to the logical elements (content-concepts and means-categories) of the text, but in a set of categories to apply to the proposed questions. At this point neither the elements of the text nor the author's ways of dealing with them were being categorized. What was being categorized was the ways that these things were to be treated in the present work, not in the document to be analyzed.

The next step in this process was that of developing a set of categories that would render it possible to classify the kinds of tasks that the resultant questions would require performed within the process of obtaining appropriate answers for them. The issues to be decided involved decisions regarding another aspect of the nature of the questions to be generated. It had to be determined whether any given question would require a description, a classification, a comparison, etc..

When the list of task types had been formulated, what then remained to be accomplished was the integration of all of the previous work: the derivation of a set of questions and answers based upon the logical elements (the content-concepts and the means-categories) of the text and the ways that these were dealt with therein, and expressed in terms of the modes and task types that would indicate the kinds of requirements that these questions would embody. What has been been described so far, then, finishes the implementation of the second of the three tasks: to describe the process that led from the textual analysis to the finished product. What remains to do is the third task: to explain how to identify the results of textual and task analysis for any given element (question and answer set) of the final result. This will be attempted now.

Since the purpose of this task is to enable the reader to identify the main textual and categorical elements that contributed to the formulation of any specified question and answer set comprising the final results of the present work, the point of departure will be the identity line that accompanies each such set. In order to implement this task, such a line will be shown here and then analyzed. First, the general meaning of each of the kinds of indicators that appear in the line will be described. And then each of the possible replacements for each indicator will be described in turn. A line from chapter III, page eighty-seven follows: "Q and A 233: page 91; line 10; type IV, i, E, d.". The first part of this line, 'Q and A 233:', assumes that the 351 questions and answers that comprise the results of this work are presented in series and numbered serially from 1 through 351, and indicates that the question and answer set being identified holds the 233rd position in that series. Chapter III (pp. 31-72) contains the question and answer sets numbered 1 through 149. Chapter IV (pp. 73-99) contains the question and answer sets numbered 150 through 278. And Chapter V (pp. 100-127) contains the question and answer sets numbered 279 through 351.

The next member of the identity line to appear, 'page 91,', indicates that the textual material used in the formulation of this question and answer set can be found on page 91 of Bunge's work. The chapter from that work that constitutes the basis of the present work can be found in the appendix. It should be noted that the indicator, 'page 91;', refers to page 91 of Bunge's work, not of either the main body nor the appendix of the present work.

After the page number indicator, 'page 91;', next appears the line indicator, 'line 10;', whose function it, obviously enough, is to indicate the line on page 91 in Bunge's work in which can be found the textual material from which this particular question and answer set was derived. This is all pretty straightforward except for one minor point. The line named by the line indicator is not necessarily the only line upon which this material appears. It can be better described as approximately the first line upon which the immediately related material appears since this material may occupy several lines or even paragraphs, and since the place where such material begins is not always clear. The difficult question here is 'At what point is the material closely enough related to the conceptual focus of the question and answer set to merit inclusion in the reference? However, it need not be inferred from the above that the situation is always or even usually that bad. Most of the time the extent of the relevant reference is clear, and even when its clarity is not optimal, it does not dip below an acceptable level.

CHAPTER III

TASK TYPES

Next after the line indicator, and comprising the balance of the line, is seen the type indicator "type IV, i, E, d.," whose four parameters will be explained below. The first of these, designated by Roman numeral IV in the sample, is designated by Roman numerals I through VIII in the complete question and answer set. The function of these Roman numerals is to indicate the nature of the task that each question requires of the student who is to answer it. The questions are grouped together under each task designation in such a way that task I comprises questions and answers 1-8; task II comprises questions and answers 9-149; task III comprises questions and answers 150-155; task IV comprises questions and answers 156-254; task V comprises questions and answers 255-258; task VI comprises questions and answers 259-278; task VII comprises questions and answers 279-347 and task VIII comprises questions and answers 348-351.

In the process of describing these tasks, the expression, "semi-schematic form" will be used. The expression is meant to denote the result of an attempt to simplify and formalize questions and answers to some degree in order to provide a glimpse of their logical structure. No pretense is made that these results will have been formalized sufficiently to make it possible to translate them into rigorous symbolic form. They are meant only as aids in understanding the various tasks and in revealing the similarities and differences among them.

Task I is centered on the concept of definition. Questions of this set take the semi-schematic form "What is an X?" or the equivalent. An X in this case is some central concept such as referent or model object. The skeletal form then fills out to "What is a referent?" or "What is a model object?" The answer can be expected to assume a semi-schematic form equivalent to "An X is a Y that possesses the set of attributes Z. The term "Y" represents a wider class of objects or concepts than does "X," and "Z" represents a set of attributes that distinguishes an X from other elements of Y. By making appropriate substitutions, something on the order of "A theoretical model is a hypothetico-deductive system concerning a model object." is obtained. "Concerning a model object" does not follow the prototypical adjectival formula for attribution. Nevertheless, to say that a hypothetico-deductive system concerns a model object does, in a wider but still legitimate sense, express attribution. Thus, task I requests a definition which, in these questions, implies placement in a wider class plus sufficient attribution to enable the defined concept to be differentiated from the other elements of the wider class. This ends the explanation of task I; an explanation of task II follows.

The primary thrust of task II is specification. Questions of this group require the supplying of some specific bit of information, the naming perhaps of an object, relation, principle, concept, etc. The semi-schematic form of the typical question of this group is "What object or concept that is an element of set Y fulfills the set of conditions, Z?" To put it in a slightly different form, questions of type II may be seen as requests to "Supply or name the object or concept, that is a (member of wider class) Y, and that (set of attributes or conditions) Z can be predicated of it." A set of attributes or conditions plus a genus is supplied, while a species or element of a species is asked for. For example, "What is the object, mechanism or process that a model object represents?" In this case, "object, mechanism or process" as a general class is Y. The particular object, mechanism or process asked for is X. And the attribute or predicate of being represented by a model object is Z. An appropriate answer to a question of this kind, in effect, simply supplies the species or member of the species that had been asked for by the question. Such answer would typically take the semi-schematic form, "An object or concept that is a member of class Y of which Z is predicated is X (or, an X)." A fleshed out example comes out, "The object, mechanism, or process that a model object represents is its referent." where "its referent" is X. This finishes the explanation of task II; that of task III follows.

Task III focuses on description or attribution. Questions of this type generally require one or the other of these two kinds of responses: (1) the attribution of a set of properties or characteristics that adequately describe an object or concept within a given context, or (2) the "unpacking," elaboration, or making explicit of a set of attributes that reside implicitly within some briefer, more cryptic description of a given concept. Semi-schematic forms that can represent these kinds of questions are (1) What set of attributes, Z, adequately describe an X of which set of attributes Y is predicated? or, (2) What (wider or more detailed) set of attributes Z are implied by a (narrower or more compact) set of attributes, Z, which is predicated of object or concept, X? It can be seen that, in spite of certain superficial differences, there exists a kind of rough equivalence between these two forms of the kinds of questions that implement task III. The actual phrasing of these questions does not often reveal their semi-schematic form in any obvious way. For example, either of them is capable of generating the question, "What is a more or less schematic model object?" Here, "model object" represents the object or concept, X, while "more or less schematic" represents the set of attributes, Y, which is predicated of X. Z, then, represents the set of attributes which the question is supposed to evoke in order to "unpack" Y. The answer to this kind of question turns out to be appropriately complementary to the question. It merely supplies the set of attributes of the given object or concept that, implicit in the given predicate, nonetheless serve to flesh it out. The semi-schematic form comes out "Set of attributes, Y, which is predicated of X implies (more detailed) set of attributes, Z." This, in response to the example question, filled out to "A more or less schematic model object is a model object that in some way represents its referent but does it rather crudely--leaving out many significant aspects of the referent."

Classification or categorization is the focal point of task IV. The object here is to place some object, process, or concept in some wider category, e.g., some particular in its species or some species in its genus.

The differentiation of the object, process, or concept from from other similar entities belonging to the same wider category is incidental at best. If it is at all called for, it is unessential to the performance of task. If this were not so, this task would be identical to task I, i.e., definition. Although it is superficially similar to task I--"What is a...?" being the apparent form--it differs from that task in that the request for differentia occurs, if at all, only incidentally. In semi-schematic form, the questions that implement this task comes out thus: "What is the smallest relevant class Y to which an X belongs?" where an X is the object or concept for which classification is asked for. Substituting actual concepts for X and Y, produces, "What is the smallest relevant class to which a mass cell belongs?" In actual practice, this comes out, "What is a mass cell?" The answer to a question that implements task IV, turns out considerably more straightforward than the question. The semi-schematic form shows up as, "An X is a Y," or "An X belongs to class Y." The meanings of X and Y, of course, remain the same as for the questions. The substitution of these meanings gives "A mass cell is an example of a model object." Here "A mass cell" is substituted for X, while "An example of a model object" is substituted for Y. The transparency of the equivalence of the alternate form "A mass cell belongs to the class of examples of a model object," is not detracted from by its awkwardness. This ends the explanation of task IV, and now begins that of task V.

Task V involves the general concept of comparison; this includes that of contrast. Questions of this type may ask for any of three kinds of response. They may ask for a set of attributes that two concepts or objects possess in common, for a set of attributes that distinguish two concepts or objects, or for a set of attributes that justify some value judgement that distinguishes between two concepts or objects. What these three kinds of request share are (1) that they each involve the furnishing of set of attributes and (2) that in each case, the required set of attributes serves to distinguish between two concepts or objects.

Type V questions, it has been seen, can be divided into three groups. Each of these can be represented by its own semi-schematic form. The first of these, dealing with similarities is "What set of attributes Z do concepts or objects X and Y possess in common?" The second, involving differences is, "What sets of attributes V and W serve to distinguish between concepts or objects X and Y?" And the third one, also having to do with differences is "What set of attributes Z justifies value judgement V by distinguishing between concepts or objects X and Y?" When the proper substitutions are made, the first example produces, "What set of attributes do semantic models and metascientific models possess in common?," or more idiomatically, "In what ways are semantic models and metascientific models similar?" The second example gives, "What set or sets of attributes distinguish between theoretical models and semantical models?," in a more idiomatic form, "What is the difference between theoretical models and semantical models?" And the third example come out, "What set or sets of attributes justify the preference for the theoretical model over the model object?," idiomatically, "In what way is a theoretical model far richer than the bare model object?"

The answer to each of these kinds of questions involves the supplying of the correct set of attributes, in the first case, similarities, in the second, differences, and in the third, differences that justify a preferential value judgement. In the first case, the substitutions give the semi-schematic form, "The set of attributes Z which concepts X and Y have in common is set A consisting of elements (attributes) a, b, c, d and e." Semi-idiomatically, this comes out, "The set of attributes that semantic models and metascientific models have in common consists of the possession of (a) a set of abstract statements, (b) a set of designation rules, (c) a set of semantic assumptions, (d) a set of properties linking those designation rules and semantic assumptions in such a way as to provide the abstract statements with factual content, and (e) a set of properties that make it possible for that factual content to be assigned truth values." In completely idiomatic form (for this sort of thing) this comes out, "Semantic models and metascientific models are similar to the extent that they both contain designation rules and semantic assumptions that provide the abstract statements with factual content that can be assigned truth values."

The second example, in a similar manner, gives semi-schematically, "The sets of attributes V and W that distinguish concept Y from concept X are the sets of attributes A and B." Semi-idiomatically this yields "The sets of attributes that distinguishes between theoretical models and semantical models consists of the following: for theoretical models, the attribute of consisting of statements concerning some aspect of reality and for semantical models, the attribute of serving to interpret abstract theories." In a more idiomatic form, this is obtained, "The difference between theoretical models and semantical models is that while theoretical models are sets of statements concerning some aspect of reality, semantical models are interpretations of abstract theories."

The third kind of answer returns the semi-schematic example, "The set of attributes Z that distinguishes between concepts X and Y thereby justifying preferential value judgement V is set A." Semi-idiomatically, as a result of appropriate substitutions, it becomes, "The set of attributes that distinguishes between the theoretical model and the model object, thereby justifying a preferential value judgement in favor of the theoretical model, is the theoretical model's capacity to link together the list of traits that constitutes the model object." In final form, this shows up as, "A theoretical model is far richer than the bare model object in that it links together mathematically the mere list of traits that constitutes the bare model object." These examples show that while the questions and answers that serve to implement task V display some differences of form, their basic unity is manifested by their common involvement with the closely related concepts of comparison and contrast. It is time now to turn from the consideration of task V to that of task VI.

The questions that serve to implement task VI ask for an interpretation or the meaning of an expression which may be a word, a phrase, or a sentence. In semi-symbolic form, such a question can be expressed, "What does (expression) X mean?" or equivalently, "What is meant by (expression) X?," or "What does it mean to say (expression) X?." In spite of the fact that several variants are possible, in general, the foregoing are also the virtual idiomatic forms of these questions. A few actual examples are, "What does 'The same holds, _a fortiori_ for the diagram' mean?," or "What does it mean to say that a referent is not abstract?"

The answers to these questions typically perform the function of supplying the interpretation or meaning that the questions ask for. Their semi-symbolic forms, predictably, are usually, "(Expression) X means (interpretation or meaning) Y," "By (expression) X, (interpretation or meaning) Y is meant," or "To say (expression) X means (interpretation or meaning) Y." The foregoing are also usually the idiomatic forms, although the latter sometimes comes out, "To say (expression) X is to say (expression or statements giving the interpretation or meaning for X) Y." The actual examples that correspond to the above questions are, "The same holds, _a fortiori_, for the diagram" means that the diagram, in some respects, a prototypical case of metaphor, can be expected to display its properties _par excellence_. In this case, the property in question is that of being misleading when used as the characterization of a model object," and "To say that a referent is not abstract, is to say that it is a factual referent. This means that it (purportedly) represents some concrete (real) thing or event. It has empirical content." Thus terminates the explanation of task VI and now begins that of task VII.

Task VII deals with the concept of explanation. As in the case of task II, task VII is something of a catch-all. There are so many kinds of explanation that an attempt to account for them all would not prove useful in the present context. Suffice it to say that, while an explanation can subsume any of the foregoing tasks, it must in some way go a bit farther than they do. An explanation is somewhat more comprehensive than a definition, an identification, a specification, a description, etc. An explanation frequently gives reasons, frequently accounts for some state of affairs. An explanation is often called for by means of a why-question or a how-question. Questions meant to evoke explanations can be expressed semi-symbolically thus, "What (set of reasons) Y accounts for (state-of-affairs) X?," or "What (set of statements) Y indicates the manner or mode in which (process) Y occurs?" In a slightly more idiomatic form, "Why is X so?" or "How does X occur?" Here are the true to life examples, "Why might the logical strength of a theory be expected to turn out to be inversely related to its ability to solve particular theoretical problems and to empirical testability of that theory." and "How can it be known that a linear model of a gas is a theoretical model?"

The answers to questions of this kind, it follows, simply provide the reasons or statements requested. The semi-symbolic for the answers that correspond to the above questions are, "The set of reasons that accounts for (the state-of-affairs) X is Y," or "The set of statements that indicate the manner or mode in which (process) X occurs is Y." The corresponding examples from list of questions and answers are, "The logical strength of a theory might be expected to turn out to be inversely related to its ability to solve particular theoretical problems and to the empirical testability of that theory because logical strength is gained only at the expense of empirical content, whereas particular theoretical problems are essentially about empirical content." and "It can be known that a linear model of a gas is a theoretical model because it has been stated that a linear model of a gas can mimic the condensation process. In order to mimic the condensation process, the model must specify the mathematical dimensions of the changes or movement that takes place. And if a model can specify the mathematical dimensions of the changes or movement that takes place, it must be a theoretical model." At this point, the discussion of task VII ends and that of task VIII starts.

The questions that implement task VIII ask for some kind of evaluation, that is, they ask for some kind of judgement or assignment of value. Although this assignment of value is the primary component of an appropriate response to this question, it frequently happens that some kind of explanation of that judgement seems in order. It is the fact that this asked for explanation is secondary to the evaluation that makes it impossible to classify these questions as belonging to task VII and make necessary to categorize them, rather, as belonging to class VIII. Generally, the idiomatic expression of a questions of this type tends to disguise rather than to reveal the question's inner structure. Hence, the idiomatic expression does not prove readily deducible from its semi-symbolic form. Nor, of course, is the converse the case. The following example from the questions and answers provides a case in point. Where V is some value, C is a set of (possibly problematic) conditions, and X is given concept (expressed as a set of statements), the semi-symbolic form is this, "What value of V can be appropriately applied to X under C?" Comparison with the idiomatic version shows that the derivation is not immediately obvious. "In section 10, it is stated that (1) semantical models are interpretations of formal systems that make all statements of the system true, (2) theoretical models (since their content is empirical) are never more than partially true so they cannot be semantical models, (3) the three empirical model objects described on page 112 are not always true, nonetheless (4) they constitute (or produce) semantical models. How is this possible?" In this example, (1), (2), and (4) constitute concept X, (3) constitutes condition C, but V is not asked for in a straightforward manner. The formulation of the nuclear question, "How is this possible?" represents something of a trick since it falsely assumes that X is possible under C, ostensibly asking only the manner of that possibility. The student is then required to reject the question as formulated, substitute another, "Is it in fact possible?," and answer the substituted one. Although this formulation appears logically messy, its use may be justifiable on didactic grounds. Asking the student to go beyond the rather cut and dried mechanical answering of a question to uncover a trick may tend to stimulate him to think more deeply about some of the issues that are examined in the paper and thus to encourage the development of a greater degree of intellectual penetration into their implications and subtleties.

The answers to these questions frequently conform reasonably well to the expectations raised by those questions, that is, they conform with respect to their inner structures as represented by their semi-symbolic forms. The answer to the above example gives this: "The value of V that can be appropriately applied to X under C is A." Although the idiomatic answer from the question set does not reveal this conformity in a markedly obviously way, it nevertheless can be demonstrated that it does in fact exist. First, the idiomatic version: "This is not possible, it constitutes an unexplained contradiction. If semantical models are interpretations of formal systems that make all statements of the system true (1), and theoretical, hence empirical, models are never more than partially true (2), then it is manifestly impossible for them to constitute semantical models. The value of V, namely A, in this case, is represented by sentence, "This is not possible, it constitutes an unexplained contradiction." After the implicit rejection of the ostensible question, "How is this possible?," the answer to the "real" question, "Is it possible?" is given. This answer constitutes, in effect, a negative evaluation of the claim X that "they [semantical models] constitute (or produce) semantical models." This negation is then specified as operative under the conditions C, "If semantical models are interpretations of formal systems that make all statements of the system true (1), and theoretical, hence empirical, models are never more than partially true (2)," The conclusion of the argument, "then it is manifestly impossible for them [theoretical models] to constitute semantical models," is no more than a slightly more elaborate reiteration of the opening negative evaluation, "This is not possible, it constitutes an unexplained contradiction." Thus, it can be seen that the idiomatic version does, although not obviously, conform to the semi-symbolic representation of an appropriate response to the question. This, then, by concluding the exposition of task type VIII, concludes the explanation of the series of task types, and leads to the consideration of the modes. This will be taken up in the next chapter.

CHAPTER IV

MODES

The three modes that are made use of in the classification of the question set are represented by the lower case Roman numerals, i, ii, and iii. The first of these, the indicative mode, simply indicates that the specific question being classified asks for the straightforward supplying of an answer. Its gross semi-symbolic form shows up as a brief, "What is X?" X, then, will turn out to be a definition, a classification, an evaluation or so on according the specified task type. Since this semi-symbolic form is gross, it lacks sufficient detail to distinguish one task type to which it may be applied from another. Thus, if this form is applied to task IV, X would represent a classification of the pertinent concept. If it is applied to task V, a comparison of two given concepts. Or if to task VII, an explanation of the appropriate concept. For example, in the case of this task II idiomatic realization of the above semi-symbolic form, "What is the relation between a sketch of an animal population and the animal population itself," X turns out to be a relation to be specified between two given concepts. In the case of this task VI realization of the same semi-symbolic form, "How can the relation between hypothetical mechanisms and model objects be stated in terms of subsets and supersets?," X is now a kind of interpretation, elaboration, or statement of the "meaning" of the given concept, in this case, a particular relation.

The answers to questions in the indicative mode merely involve, as might be expected, the production of the required value of X: a definition, a description, or an explanation according to the task type being implemented. The gross semi-symbolic form accordingly takes shape as, "X is A," where X is the means of expressing the required concept or statement in the question, while A performs the analogous function in the answer. The idiomatic actualization of the answer to the first of the above example-questions comes out, "The relation between a sketch of an animal population and the animal population itself is the relation that holds between a model object and its referent: the modeling relation." Here, "the relation between a sketch of an animal population and the animal population itself" is X while "the relation that holds between a model object and its referent: the modeling relation." is A. The idiomatic answer to the second of the example-questions is "The relation between hypothetical mechanisms and model objects can be stated in terms of subsets and supersets by saying that the set of hypothetical mechanisms forms a subset of the set of model objects, which is equivalent to saying that the set of model objects forms a superset of the set of hypothetical mechanisms. Here X is "The relation between hypothetical mechanisms and model objects...in terms of subsets and supersets," while A is "the set of hypothetical mechanisms forms a subset of the set of model objects, which is equivalent to saying that the set of model objects forms a superset of the set of hypothetical mechanisms." This concludes the explanation of mode i, upon which will follow that of mode ii.

Mode ii might be described as a sort of binary mode. It calls for an affirmation or denial, an assertion that some statement or claim is either true or false. The answerer is asked to choose between two possibilities, one of which is assumed at the outset to be correct while the other is taken to be incorrect. As in the case of mode i, this mode may be used to implement any of the tasks. The difference between these two modes does not involve a difference between the kinds of tasks to be implemented, but rather a difference between the manner of evoking the desired implementation. Mode ii, it turns out, offers considerable more in the way of restrictions or guidance with respect to the kind of answer expected than does mode i.

Again, the semi-symbolic examples to be considered here will reveal only the gross structure of mode ii while obliterating the details of the various tasks. Basically equivalent but superficially variant forms are, "Is situation X the case or is it not?" and "Which is the case, situation X or situation Y?" Both offer examples of the disjunctive form which implies a background in which the universe with respect to the problem being considered is divided into two mutually exclusive but conjunctively exhaustive possible states of affairs. The possibility of the existence of a third state of affairs in which the question has been misapplied has been implicitly rejected ipso-facto by the use of this form. Normally, with a question of this type asked in good faith, it can reasonably be expected that this division of the universe of discourse fairly represents the situation being discussed. Nevertheless, the possibility that didactic strategy might suggest the employment of devious methods (as in the case of task VIII) cannot be entirely ruled out. To recognize the equivalence the above examples, it need only be considered that the negation or falsity of situation (represented by a statement) X in the former is equivalent to the affirmation or truth of situation Y in the latter because of the mutual exhaustiveness implicitly assumed in both cases.

The former example converted to idiomatic form gives, "Does the set of entities: 'the set of bodies,' 'the temperature,' 'the quantity of heat per unit mass,' and 'the specific heat at constant volume' constitute a semantical model?" Here the constitution of a semantical model by the set of entities: the set of bodies, the temperature, the quantity of heat per unit mass, and the specific heat at constant volume is the current value of X, while the failure of said constitution is the value of not-X (the denial or falsity of X). The conversion of the second example to idiomatic form results in, "Is the Rashevsky citation meant to inform the reader about how to go about performing a scientific investigation, or what?" Here, the present value of X is the truth of the statement that the Rashevsky citation is in fact meant to inform the reader about how to go about performing a scientific investigation, while the "or what?" represent the value of its denial. Furthermore, the addition of the phrase "or what?" invites the inclusion of an alternate definition of the situation in case that the response denies the truth of X. Certainly this example constitutes something of a variant of the cited semi-formal case where both alternatives are explicit as opposed to the above idiomatic version in which one is implicit. Nonetheless, the general principle, although perhaps not transparent, is adequately illustrated by these examples.

The relation of the semi-symbolic forms of the answers of mode ii questions to those of the questions themselves interjects few surprises. In the first case, what is asked for is a choice between the affirmation or the denial of the truth of a statement outlining a proposed situation. What the answer gives is essentially that. The semi-symbolic representation gives either, "X is the case (is true)" or "X is not the case (is false)." In the latter case, non-logical (didactic) considerations may prompt the expectation that the answer will contain some sort of supplementary explanation or alternative suggestion, but such an inclusion would constitute a secondary adjunct to the primary selection of choices. In the case of the semi-symbolic form of an answer to the second example, the inclusion of a statement delineating an alternate state of affairs along with a possible explanation is explicitly called for. The semi-symbolic form that reveals the skeletal structure of this type of question is, either "X is the case and Y is not the case," "Y is the case and X is not the case." Whether or not Y is stated explicitly as a possibility or merely explicitly called for without being named can be of paramount importance for certain purposes, but not for those of the present work.

The idiomatic versions of these examples conform predictably to the expectations raised by the semi-symbolic representations of their underlying structures. The first gives, "No. The set of entities 'the set of bodies,' 'the temperature,' 'the quantity of heat per unit mass,' and 'the specific heat at constant volume' does not constitute a semantical model." Here, the answer is little more than a flat denial that the proposed situation does in fact obtain. The second example gives this possible realization of its semi-symbolic form: "The Rashevsky citation is not meant to inform the reader how to go about the performance of a scientific investigation, but to describe some of the essentials of scientific investigation as necessarily performed by practicing scientists." Here X, i. e., the truth of the statement that the Rashevsky citation is not meant to inform the reader how to go about the performance of a scientific investigation, is rejected while an alternative, Y, i. e., the statement that the Rashevsky citation is meant to describe some of the essentials of scientific investigation as necessarily performed by practicing scientists" is proposed and certified as true. The nature of the task that a question is meant to evoke, it can be seen, is a matter of indifference to the mode. Whether the given task involves a definition, a comparison or an explanation has little bearing per se on the selection of the mode that is to evoke it. Mode ii questions simply offer the choice between the acceptance or rejection of a given definition, comparison or explanation, or else they ask for choice between alternate definitions, comparisons, or explanations. The discussion now turns from the consideration of mode ii questions to the contemplation of those of mode iii.

Mode iii questions involve deduction or inference. They ask the answerer to go beyond the explicitly stated facts to attempt the discovery of the implicit. While the structural details of these questions vary considerably, the overall structure merely serves as a framework for supplying premises and the asking for a conclusion. The semi-symbolic form that shows this structure amounts to, "What relevant statement Y can be deduced from set of premises X?" The main difference between mode iii questions and those of modes i and ii is that the answer asked for does not appear in the demonstration document in explicit form at all; it can be obtained only by inference. One idiomatic realization of this form produces, "If one of the aims of research were to be instantaneously and universally realized, what would be the effect on all black boxes?" It can be noticed that this example turns out doubly obscure. Not only does it call for the production of an inference, but only a hint is given as to the exact content of one of the premises. The identity the "aim of research" being talked about in this question is not given; it is only by a perusal of the demonstration document at the specified location that the context will supply the means of ascertaining this information. The relation between this, the dominant "aim of research" dealt with in the document both as a whole and at the specified location, and the expected answer, a projected result of said "aim," is so close it would have been difficult if not impossible to ask the question without virtually revealing the answer. The set of premises X, then, includes both the unstated premise that identifies the relevant "aim of research," and the explicit premise, "one of the aims of research 'is' (were to be) instantaneously and universally realized." The expected conclusion Y is a statement that identifies, "the effect on all black boxes," consistently with the content of the set of premises X.

The answer to this kind of question follows the expected formula, consisting essentially of nothing more than the revelation of the conclusion asked for by the question. The semi-symbolic form in point, "A relevant conclusion Y that can be drawn statement X is A." A, here, is the specific present case value of the generic conclusion Y. The idiomatic version comes out, "If one of the aims of research were to be instantaneously and universally realized, all black boxes would be converted into built-up models. Since one of the aims of research is to throw further light into every box, the accomplishment of this aim would change all black boxes into built-up models or, at least, into grey boxes." "One of the aims of research is to throw further light into every box," makes specific the unstated premise to complete set X, while, "the accomplishment of this aim would change all black boxes into built-up models or, at least, into gray boxes," constitutes the asked for conclusion. This ends the discussion of mode iii questions in particular and of question-modes in general. Next to be considered are twenty "content-types" that designate the conceptual categories that the author of the demonstration document has employed in dealing with his subject matter as an integral component of the process of exposition. These will be considered in the following chapter.

CHAPTER V

CONTENT TYPES

The "content-types" are not, as in the cases of the task-types or the modes, to be found solely in the questions; their primary source is the demonstration document itself. It is from there that they find their way into the questions. In general, it is to be understood that underlying every question can be found a particular kind of content-type called here "concept-type." In the discussion of the demonstration document these four concept-types have been named, "referent," "model object," "theoretical model," and "general theory." Although at least one of these concept-types can always be found in the background of any of the questions, this may or may not be true of the foreground. And what the term "content-type" designates is what is in the foreground.

It does happen, however, that sometimes one or more of the concept-types is found in the foreground, and when this happens, an "A" appears in the classification line of the question wherein this occurs. This indicates that one or more of the concept-types is to be found at the conceptual focal point of the question in an explicit, rather than in a merely implicit form. Whether or not one or another of the specific content-types is to be encountered there is only remotely material to the form, semi-symbolic or otherwise, of the questions and answers. Thus no attempt will be made to associate given content-types with specific semi-symbolic forms or, for that matter, with specific modes or task-types. At least theoretically, and for the most part in practice, any content-type might be matched with any mode or task-type. Furthermore, any number of content-types might theoretically show up at the focal point of any given question, though the practical limit is perhaps about four or five. An example of content-type A in which the specific concept-type is referent is, "What is a referent?" And the answer comes out, "A referent (of a particular model object) is the object, process or bit of reality that is represented by that model object." Mutatis mutandis, for the model object is obtained, "What is a model object?" along with its corresponding answer, "A model object is a schematic representation of an object or process, that is, a schematic conceptual representation of a thing or of a situation assumed to be actual or possible." Analogous methods would, of course, give analogous results for the two remaining concept-types. Both of these examples obtained from task I, mode i questions, but content-type A question and answers may be encountered in association with many combinations of tasks and modes. Here, for confirmation of this fact, is an example of concept-type A combined in a question with task VIII, mode ii: "Are theoretical models necessarily true?" with its answer, "No. Theoretical models are not necessarily true; they may be either true or false."

"What is a general theory" constitutes an example of a content-type A question in combination with mode iii. Its answer is "A general theory is a theory (a hypothetico-deductive system) that has a particularly wide range of application by virtue of the fact that it contains only high level abstractions, which is to say that it has no specific empirical content." This is a mode iii question not by virtue of any attribute or attributes of the question itself, but because the lack of an explicit definition of the term "theoretical model" in the demonstration document. The preceding example is particularly apt in that it serves the purpose of rounding out this exposition of content-type A in combination with both the remaining mode, mode iii, and the remaining concept-type, the general theory, before turning to the consideration of content-type B.

Content-type B questions tend to revolve around the concept of description. They generally involve a property, attribute, characteristic, or something of that sort.

whether they in some way identify, specify, describe, classify, compare, interpret, explain, or evaluate the involved attribute or attributes depends upon their task-type. It should be noted that, in accordance with already given description of the relation between task-types and content-types, one task-type may be found paired with several content-types, but not vice-versa. An example of a content-type B question: "What feature of crude (simple) models frequently renders them more instructive that more complicated models?" And the corresponding answer: "The feature of crude (simple) models that frequently renders them more instructive than more complicated models is the exactness or precision of the solutions that they provide." Here, it is obvious that the term, "feature," is one "of that sort" that fits in with attribute, etc. Now, the discussion turns from the consideration of content-type B to that of content-type C.

Content-type C questions deal with alternate kinds, sorts, types or varieties of concepts. It happens so frequently that the particular entity to be varied turns out to be one of the four basic concept-types that it may be assumed that content-type C questions, as well as questions of any other content-type, at least implicitly subsume the consideration of at least one of the four basic concept-types. This means that virtually every question may be considered to be a sort of "soft" content-type A question. Since this "soft" attribute of the questions is ubiquitous, there is no distinction to be made with respect to it. Consequently, the content-type labels that appear in the identification lines of the questions do not contain any indication that this attribute exists. It is only when one of the concept-types appears explicitly as a central focal point of the question that the question is labeled content-type A; in which case it is not a "soft" Content-type A that is under consideration, but a "hard" one. The distinction between "soft" and "hard" A's can be illustrated by means of the following examples: The question, "What is a model called if it has an input and an output along with internal variables, but no explanatory mechanism?" and the corresponding answer, "A model that has an input and an output along with internal variables but no explanatory mechanism is called a grey box," provide an example of a content-type C question-answer that is an implicit or soft content-type A question-answer. As a soft content-type A question-answer, its only content-type label is "C." Whereas the question, "What are non-realistic abstract situations?" along with its answer, "Non-realistic abstract situations are, in effect, model objects in which only certain significant aspects of the referent are modeled. All other aspects of the referent are ignored," provide an example of a content-type C question-answer set that is also an explicit or hard content-type A question-answer set. The first example serves as an example of a content-type C question-answer set because a grey box is a variety of a concept. It is an example of an implicit or soft content-type A because the grey box exemplifies a kind of model object or theoretical model, both of which fit into the content-type category. The second example provides an example of a content-type C question-answer set that is also an explicit or hard content-type A because the fact that "non-realistic abstract situations" represent a variety of model object looms larger and more central here than does the analogous fact in the first example. The foregoing, it is hoped, provides an adequate view of the meaning of "content-type C" and the focus of attention can now turn to the consideration of content-type D.

Content-type D questions have to do with relations or connections of some kind or other. Again, the identity of the task-type will determine whether the particular relation or connection under consideration is to be classified, compared, or explained, etc. The discovery that the relations dealt with by means of content-type D questions tend most frequently to link one concept-type with another is beyond a doubt minor. For example, the question, "What is the relation between a continuum endowed with certain properties, such as compressibility and viscosity, and a fluid?" and its concomitant answer, "The relation between a continuum endowed with certain properties, such as compressibility and viscosity and fluid is the relation that holds between a model object and its referent: the modeling relation," relate the concept-types, model object and referent. The relation between these two concept-types, model object and referent, occur in the present document more frequently than any others. As another example, take the question, "How are the sun (along with its optical and gravitational manifestations) and a rotating ellipsoid or a mass point related to each other?" Look at it together with its attending answer, "The sun (along with its optical and gravitational manifestations) and a rotating ellipsoid or a mass point are related to each other in the following way. The sun (along with its optical and gravitational manifestations) is an example of a referent for which a rotating ellipsoid or a mass point is an example of a model. Conversely, a rotating ellipsoid or a mass point is an example of a model for which the sun (along with its optical and gravitational manifestations) is an example of a referent," These provide a case in point. While in the preceding cases, both elements of the relation in question proved to be concept-types, it sometimes happens that one or the other of the elements turns out to be something other than a concept-type. Witness the example: "How can the relation between hypothetical mechanisms and model objects be stated in terms of subsets and supersets?" with its corresponding answer, "The relation between hypothetical mechanisms and model objects can be stated in terms of subsets and supersets by saying that the set of hypothetical mechanisms forms a subset of the set of model objects, which is equivalent to saying that the set of model objects forms a superset of the set of hypothetical mechanisms." Although one of the elements of the relation being discussed (model object) is a concept-type, the other, while closely related, is not. The other element of this relation, although not in itself a concept-type, nevertheless has been defined as a set of them. It constitutes in fact _a_ set, although not _the_ set of model objects. Here the discussion of content-type D is concluded and that of content-type E is begun.

Concept-type E questions relate to examples and instances. Expository confrontation with the basic concepts of a discipline entail the almost ubiquitous use of examples. Examples generally represent particular concrete applications of more or less abstract concepts. It might be said that the function of an example is to provide the realization of those idealizations that are termed "concepts." The question, "What is the purpose of the examples of the mechanisms of electromagnetic propagation, of complex chemical reactions, and of biological evolution?" along with its expected answer, "The purpose of the examples of the mechanisms of electromagnetic propagation, of complex chemical reactions, and of biological evolution is to combat the identification of the concepts of model and mechanism, that is, to show that the concept of model is broader than this identification would suggest that there are models that are not mechanistic," provide an example of questions wherein the fact that they are about examples is explicit. Whereas the question, "What is the referent of which the sociological interpretation of the symbols, 's', 'F(s)', 'G(s,s')', and 'G(s,s')' constitute a model object is the probability of migration taking place between one given country and another," supplies an example in which the analogous fact can be seen to be only implicit. Nowhere in the test of the latter question and answer does the term "example" appear. Nevertheless the expression "constitute a model object" can--indeed, in the present context, must--be interpreted as meaning "constitute an <u>example</u> of a model object." In consonance with earlier findings, it is found that the foregoing all involve examples of one or more concept-types. While this situation is not invariable, even the exceptions adhere to its spirit. The question, "What are the symbolic diagrams that correspond to the alternative representations of the motion of the set of coupled oscillators?" with the adjunct answer, "The symbolic diagrams that correspond to the alternative representations of the motion of the set of coupled oscillators are examples of heuristic devices that render the alternative representations more intelligible while remaining merely adjuncts to, and not parts of, those model objects," constitute an example of a case in which, although the example is not of a concept-type, it nonetheless does bear an intimate relation to a particular concept-type, to wit: the model object. Even though the raison d'etre of the question involves the making of the point that the relation between the symbolic diagrams and the model objects is not as close as it might appear to be, the raison d'etre of the symbolic diagrams is just that relation. The discussion now turns from the consideration of concept-type E to that of concept-type F.

Concept-type F questions deal with classifications and categorizations. The first problem that arises in this connection is that, at first glance, concept-type F seems to duplicate task-type IV, since they both deal with classification or categorization. This apparent duplication, however, proves more illusory than real. The difference between concept-type F and task-type IV resides in the fact that while task-type IV questions ask <u>for</u> a classification or categorization of some concept or other, i. e., a content-type or a concept-type, the concept-type F questions ask <u>about</u> some classification or categorization that has already been embedded either explicitly or implicitly in the text being analyzed. It should not be imagined, however, that the designations "task-type IV" and "concept-type F" must inevitably be applied in a mutually exhaustive manner. Since it is possible to ask <u>for</u> a classification or categorization <u>about</u>, or perhaps <u>of</u>, another classification or categorization, it follows that the two designations can be applied simultaneously. This is, of course, consonant with the principle that any task-type can, at least theoretically, be combined in one question with any content-type. Also, it should be remembered that any content-type can, in principle, be combined with any other content-type in the same question. On the other hand, the fact that task-type IV <u>may</u> combine with concept-type F does not entail that they _must_. As a matter of fact in the set of questions and answers that constitutes perhaps the most palpable part of the results of the present work, they do not.

An appropriate move at this time is to consider the question, "Why does not the set of entities 'the set of bodies', 'the quantity of heat per unit mass', and 'the specific heat at constant volume' constitute a semantical model?" Next, it should help to look at the answer that this question might expected to evoke, "The set of entities 'the set of bodies', 'the quantity of heat per unit mass', and 'the specific heat at constant volume' does not constitute a semantical model for these reasons: (1) this set of entities constitutes a factual interpretation of the mathematical system, F1 through F4, (2) it is a factual interpretation,of the purely formal system, A1 through A5, (3) it does not make these systems come out true in every case, (4) a factual interpretation, in fact _any_ interpretation of a formal system that does not make that system come out true in all cases fails by definition to constitute a semantical model." This question-answer set is typical of many of those of content-type F in that it is _about_ a classification without asking for a classification. What it does ask for is an explanation of why a given classification, i. e., the classification of a given set of entities as a semantical model, does not hold. It is appropriate at this point to turn from the discussion of content-type F questions to that of questions categorized as belonging to content-type G.

The kind of concept that content-type G questions involve can be suggested fairly well by such closely related, but not entirely synonymous terms as "function," "purpose," "goal," "end," "use," and "application." The lack of a precise definition of the scope of this category is not really a fatal disadvantage here. In the 8resent application, an indication of the general location and boundaries of the conceptual area covered by these questions is adequate. The question, "Why are theoretical models necessary to science?" and the appropriate answer, "Theoretical models are necessary to science because they alone are testable," serve to exemplify the content-type G question-answer set. The unstated premise of the argument contained in the answer is that testing is necessary to science," Here, the testability of the theoretical model explains its usefulness in the context of scientific investigation. Another question, "What are the three chief functions of theoretical models?" must here be considered. This question, along with its answer, "The three chief functions of theoretical models are these: (1) the posing of specific theoretical problems, (2) the solution (explanation) of specific theoretical problems, and (3) the testing of proposed solutions (explanations)," brings up the problem of scope. In this respect the former and the latter question-answer sets somewhat overlap. While the former question was answered by naming a property that implied a function, the latter was answered by specifying three directly asked for functions. The important fact here is that functions or more or less closely related concepts are always prominent in content-type G question-answer sets. This concludes the treatment of content-type G questions and signals the start of the exposition of content-type H questions.

Content-type H questions concern themselves with a concept-cluster that can be hinted at by such terms as "method," "procedure," or "process." What is involved here are the principles that relate to the way that something occurs or is done. Look at the question, "In a field of research like contemporary mathematical sociology which has tended to produce isolated bits of knowledge rather than unifying concepts, how are theoretical models typically constructed?." Here, a way of accomplishing something, a method, is called for. The appropriate answer is, "In a field of research like contemporary mathematical sociology which has tended to produce isolated bits of knowledge rather than unifying concepts, theoretical models are typically constructed by building them around model objects. This is usually done by expanding the model into a mathematically oriented hypothetico-deductive system." This answer fulfills the requirement of the question by specifying the asked for procedure by means of its description. It can be noted here that the above example is a task-type II question, i. e., a question that requests specification, rather than a task-type III question, i. e., a question that asks for a description, because the description is only the means of accomplishing the specification--a secondary end rather than a primary one.

Consider the question, "Why is an explicit statement of the semantic assumptions mandatory in the axiomatic reconstruction of a scientific theory?" Its answer is "An explicit statement of the semantic assumption is mandatory in the axiomatic reconstruction of a scientific theory because the same mathematical formulas will sometimes fit more than one referent. For example, the flow of water in a pipe can be represented by the same (or analogous) formulas as the flow of electricity in a wire. Thus, an explicit statement of the semantic assumption is needed to make sure that there is no confusion regarding which formula is being linked to which referent," This constitutes an example of a content-type H question that does not ask for a method or a procedure. This question rather asks for an explanation regarding a procedure. Since asking for an explanation defines a task-type (task-type VII) and not a content-type, it is because of the fact that the required explanation is about a procedure that this question is categorized as content-type H. Here ends the discussion of content-type H, and starts that of content-type I.

The concept-cluster that constitutes the subject matter of content-type I questions is suggested by such terms as "result," "outcome," "upshot," or "effect." Something that happens because something else has occurred is what lies at the focal point of these questions. Examine the question, "What is the result of specifying the boundary and initial conditions, the mass and stress distributions, and the external forces for the oscillation of a shell?" Here, a cause, the "something else" is specified and a result is specifically asked for. The "something else," the cause, is the specification of the boundary, the initial conditions, etc. for the oscillation of a shell. Now look at the answer that this question might be expected to evoke, "The result of specifying the boundary and initial conditions, the mass and stress distributions, and the external forces for the oscillation of a shell is a model object." In this answer, the requested result is (the production of) a model object. The preceding example illustrated the concept-type I question wherein a result is specifically asked for. But there are content-type I questions wherein the reference to a result is less obvious. Take, for example, the question, "What can be accomplished with a continuum endowed with certain properties, such as compressibility and viscosity?" Here the "something else" that is to generate the expected result is "a continuum endowed with certain properties, such as compressibility and viscosity," More accurately, it might be said that the "something else" is only indirectly referred to by the expression, "a continuum...etc." What the "something else" really is refers to is some process that is connected in some unspecified way with "a continuum...etc." The expected result in this example is obliquely referred to as "what can be accomplished." Now look at an answer that fits that question, "A continuum endowed with certain properties, such as compressibility and viscosity can be conjoined with (grafted onto) classical mechanics, general relativistic mechanics or some other general theory to produce a theoretical model of a fluid." It can now be seen that this answer explicitly names the called for result, i. e., the production of a theoretical model of a fluid. Moreover, the "something else" is now directly specified as the conjoining of "a continuum endowed with certain properties, such as compressibility and viscosity" with "classical mechanics, general relativistic mechanics or some other general theory." Here, the discussion of content-type I breaks off and the consideration of content-type J begins.

Content-type J questions deal with the concept-cluster that is suggested by the terms, "term," "expression," "name," and "designation." These questions tend, to a considerable extent, to revolve around linguistic entities. They may describe these linguistic entities, interpret them or explain them etc. according to the natures of the various task-types that govern them. These linguistic entities, of course, are always linked, either immediately or ultimately, with one of the four basic concept-types: referent, model object, theoretical model, or general theory. Consider, for example, the question, "What expression designates a model object that concerns itself only with accounting for the end results of the referent without attempting to explain how these results are obtained?" This question requires the specification of a expression that fulfills certain conditions, namely that it designate "a model object that concerns itself only with accounting for the end results of the referent without attempting to explain how these results are obtained." Take now an appropriate answer to this question, "The term that designates a model object that concerns itself only with accounting for the end results of the referent without attempting to explain how these results are obtained can be termed a black box." This answer satisfies the question by specifying the called for expression: "black box." Similarly, regard the following content-type J question, "What could a theoretical model that has been "confirmed" be termed to show that, to some extent (albeit inadequately), it fulfills the requirements that make it possible to constitute a semantical model?" Here again, a term is asked for that fulfills certain conditions, i. e., that it be applicable to theoretical models that have been confirmed, and it that it "show that, to some extent (albeit inadequately), it fulfills the requirements that make it possible to constitute a semantical model" Look at an appropriate answer to this question, "In order to show that, to some extent, a "confirmed" theoretical model fulfills the requirements that make it possible to constitute a semantical model, it could be termed a "quasi-model.'" This answer fulfills the requirements of the question by supplying the requested term: "quasimodel." At this point, the discussion turns from the consideration of content-type J to the examination of content-type K.

Content-type K questions deal with a concept-cluster that is suggested by such terms as "sign," "symbol," and "representation." These questions invariably involve something that stands for something else. The question, "What does R represent?" supplies the "something that stands for something else," i. e., R, and asks what it is that R stands for. The answer, "R represents a referent," tells what it is that R stands for, i. e., a referent. The relation of the "something that stands for something else" to the question or answer as a whole, however, is not always so direct. Regard the content-type K question, "What can be done to remedy the excessive coarseness and lack of economy characteristic of the description of the model wherein the paired inputs and outputs are tabulated?" This question does not simply ask for either the entity that stands for something else or the entity for which it stands. It asks, rather, for a prescription, for a method of constructing a better something that stands for something else. Here is an appropriate answer, "To remedy the excessive coarseness and lack of economy characteristic of the description of the model wherein the paired inputs and outputs are tabulated, the ordered pairs can be implied by means of a rule rather than stated explicitly by means of a table." The answer, accordingly, supplies the method of constructing the entity that represents something else that the question requests. Thus ends the discussion of content-type K questions and starts the discussion of content-type L questions.

Content-type L questions involve the concept-cluster suggested by such terms as "statement," "proposition," "system," or "theory." Here, the clarification should be made that the "system" mentioned above is primarily a linguistic system, or that, at least, that the questions are oriented primarily toward the linguistic aspects of any non-linguistic system under consideration. Another of approaching this might be to say that, to what ever extent the kind of "system" being discussed here is not linguistic, it is a conceptual system of some kind or other expressed linguistically. And while the object-document may in some cases deal primarily with the concept of which the linguistic entity is only a representation, the type L question primarily confronts that representation; its involvement with the underlying concept is only secondary.

As an example of the type L question's concern with the linguistic entity, consider the following example: "Why does the set of statements, 'the capital letters are sets or functions, "R" is the real line, "o" is the arithmetic product, etc,' fail to qualify as a semantical model?'" Here the classification of the linguistic entity, the set of statements, is all that is being questioned; the nature of the underlying mathematical concepts gains relevance only by virtue of their use as an example. A suggested answer to this question is, "The set of statements, 'the capital letters are sets or functions, "R" is the real line, "O" is the arithmetic product, etc,' fails to qualify as a semantical model because, while it is an interpretation of the system of the signs, A1 through A5, it does not make the system true in all cases." This answer explains why the mentioned linguistic entity fails to qualify as a semantical model. The understood missing premise in this case is the definition of a semantical model as "an interpretation of a theory that makes the theory come out true in all cases." This premise is an example of the kind of basic knowledge that the student is assumed to possess at the outset. The question and answer set could, of course, be programmed to vary the prerequisite level of sophistication, but consideration of the implications of this possibility lie beyond the scope of the present work.

The focal point of a type L question, i.e., some subset of the set of linguistic entities, need not be represented formally. Take, for example, "What is the reason for saying that simplicity is the privilege of either total ignorance or extreme generality (no detail)?" In this case, the linguistic entity central to the question is expressed by a mere paraphrase of an informal, perhaps somewhat epigrammatic, comment made in the course of the expository process. The answer suggested for this question is, "The reason for saying that simplicity is the privilege of either total ignorance or extreme generality is to justify the complication of theoretical models." This answer supplies the asked for purpose for the inclusion of the linguistic entity in the text.

Look at one more example, "Why is every formula containing the symbol of the modeling relation either an interpretative axiom or a semantic assumption?" The linguistic entity at the heart of this question is the set of formulas "containing the symbol of the modeling relation." This definition of the set of formulas under consideration may appear to emphasize the contents of the these formulas. But this appearance is not to be relied upon. This prerequisite barely indicates the general type of formula being dealt with in the text; it leaves plenty of room for variety. Any formula of this type links a model object, and hence a theoretical model to its referent But that referent can be a behavior or a structure, an object or a concept; it can be statistical or functional Moreover, given the referent, the type of model object can vary greatly In fact there can exist an infinite number of models for each referent any one of which must be classified as either "an interpretation or a semantic assumption." This example, then, like the previous ones sustains the thesis that type L questions deal with linguistic entities per se and only peripherally with their contents. A suggested answer to this question is, "Every formula containing the symbol of the modeling relation is either an interpretative axiom or a semantic assumption because such a formula relates a theoretical model to its referent, as, for example, the theoretical model s of a cell to the referent, or real cell r." This answer merely explains why a formula of this kind always turns out to be either an interpretive axiom or a semantic assumption--rather anticlimactic, really. With this, the exposition advances from the consideration of content-type L questions to the explication of those of content-type M.

Content-type M questions involve the juxtaposition of concepts for the purpose of making contrasts by means of noting the differences between them. This example, "What is the difference between deterministic models and probabilistic models," is quite straightforward. It simply asks for the specification of the principle difference between two concepts. The answer to this question, "The difference between deterministic models and probabilistic models is that deterministic models predict (or attempt to predict) what will occur under certain given conditions, whereas probabilistic models try to predict what may happen under given comditions while indicating in mathematical terms what the chances are that this or that event will or will not occur," is not quite so simple. Nonetheless, neither is it very complicated. It specifies the required difference between the named concepts in terms of a contrast between the kinds of performance expected of each.

The next example, "What is the importance of contrasting users with designers or scientists with engineers?" is almost as direct. Judging from the question, the ways that this example differs from the previous one are embodied first, in the occurrence of a double contrast and second, in the more significant change in the sort of thing that is asked for. Since a single answer is apparently expected to suffice for both contrasts, it is fairly obvious that they are in some way analogous and that they do not really represent two different contrasts. One the other hand, whereas the first example asks for the specification of the difference that constitutes the contrast, the second requires an explanation of the author's purpose in presenting it. In this case, the contrast itself assumes a secondary importance, what is primary is its function. Nonetheless, knowledge of what the contrast consists of is assumed. The answer, "Users are contrasted with designers and scientists with engineers to show how the model's application should determine whether a dark box or a built-up model is chosen. Where mere use is contemplated, the dark box model is adequate, but where knowledge is desired, a built-up model is needed," contains a similar assumption. It is taken for granted that users and scientists are interested in mere use, while designers and scientists are interested in knowledge. The nucleus of this response is the explanation that links the choice of model type with the particular interests of those who choose.

Sometimes, it happens that a content-type M question is not immediately obvious as such. The question, "What error does the 'semantical freak' involve?" illustrates this. The only way of knowing that this is a content-type M question is by reference to the answer, "The 'semantical freak' involves a confusion between theoretical model and referent. The theoretical model is discussed as though it were the referent." Here it can be seen that what is involved is a confusion that can be resolved by marking well the contrast between two concepts. Thus, it is the answer that unmasks the question as belonging to content-type M. This ends the discussion of content-type M questions; next starts the consideration of those of content-type N.

Content-type N questions tend to focus on principles, rules or paradigms that may or may not serve as criteria for arriving at some decision or conclusion. These principles, etc. may be encountered in the form of hypotheses or assumptions of some kind or other, or even in the form of philosophical stances or attitudes. They play various roles in the questions. A look at some examples will help to illustrate this.

The question, "What criteria were applied in order to determine the falsity of Ising's model object?" serves as the first of these. It requests that a set of principles that serve as criteria be specified. These criteria have been used in relation to the performance of a given function. Here is the suggested answer to this question, "The criteria that were applied in order to determine the falsity of Ising's model object were the relatively greater prestige of the general theory (statistical mechanics) and the principle that requires a theoretical model to represent every significant (relevant) aspect of its referent if it is not to be considered false." This answer simply specifies the (two) requested criteria.

The question, "What would be the likely result of the universal application of the black boxist philosophy?" is another story. Here, the principle is not asked for, but specified at the outset. Only the name of the principle, referred to as a philosophy, is given, not its content. Knowledge of the content is assumed, therefore it is tested--obliquely, of course. The primary given, by this question, is a hypothesis of the application of the principle. In summary, then, the form of the question is that of a conditional whose antecedent is the hypothesis of the application of the principle and whose consequent, the conjectured results of that application, is asked for. It should be mentioned at this point that the asked for conjecture does have to be made by the student, it has been made by the author; the student is, in substance, asked to do no more than to recognize it for what it is. The answer to this question, "The likely result of the universal application of the black boxist philosophy would be the immediate drying up of the sources of scientific knowledge and, consequently, an eventual halt to scientific progress." yields no great surprises. It supplies a two step conjectured result which takes on the rough outlines of the valid form,

$$[(p \rightarrow q) \& (q \rightarrow r)] \rightarrow (p \rightarrow r).$$

where p is interpreted as "The black boxist philosophy is universally applied," q as "The sources of scientific knowledge immediately dry up," and r as "Scientific progress eventually halts." It was necessary to talk about the "rough outline" of the form because

$$p \rightarrow q$$

(the universal application of the black boxist philosophy will immediately dry up the sources of scientific knowledge) and

$$q \rightarrow r$$

(the drying up of the sources of scientific knowledge will cause an eventual halt to scientific progress) are givens and not hypotheses--they are assumed to be true at the outset. What is asserted then is not that _if_ these conditionals are true _then_ the application of the black boxist philosophy will cause an eventual halt to scientific progress but rather that _since_ they _are_ true, the application of the black boxist philosophy would eventually cause scientific progress to halt. Thus, although the argument does follow the "rough outlines" of a tautologically valid form, it is not itself logically valid but merely consistent. This is not to be considered a defect in the argument since its essentially empirical character dictate that it be judged primarily in the light of empirical criteria. Whether or not it is found to be "sound" will depend presumably upon "the state of things" although in actuality it may depend to a considerable extent upon one's philosophical leanings.

While in a sense the black boxist philosophy stands as the focal point of the question, in another it is situated in a secondary relationship to the supposition that it is applied--its application. If this seems like splitting hairs, it should be noted that a principle (or an attitude or a philosophy) is <u>not</u> identical to its application. To speak (directly) about a principle is to deal with it internally, while to discuss its application is to deal with it externally and to talk about it only indirectly. To deal with a principle internally is to talk about the composition of its components and how they relate to each other. To deal with it externally is to consider its relation to other concepts, objects or events. The object of this example is to show how a principle can be displaced from the logical center of a concept-type N question without substantially surrendering its position at the conceptual center.

"Why might the black box paradigm be expected to encourage superficiality?" is the final example of a content-type N question to be considered. Here, the given is the name of a paradigm (rule, or principle) along with a conjecture as to the probable results of the application of that paradigm. What is required is a justification of the conjecture. This is supplied by the answer, "The black box paradigm might be expected to encourage superficiality because of the fact that this paradigm, by implication, ignores the possibility of the existence of an internal structure and mechanism of its referent. Thus, the paradigm discourages the attempt to discover the internal structure and mechanism whose existence it ignores." The argument approximates the valid form,

$$[(p \rightarrow q) \ \& \ (q \rightarrow r)] \rightarrow (p \rightarrow r).$$

where p is interpreted as "The black box paradigm is applied," q as "The internal structure (of a referent) is ignored," and r as "The attempt to discover internal mechanisms is discouraged." This argument depends first of all on the truth of p -> q, the claim that the black boxist paradigm implies ignorance of "the possibility of the existence of an internal structure and mechanism of its referent." Second, it depends upon the truth of a supressed premise that mediates q -> r (to ignore "the possibility of the existence of an internal structure and mechanism of the" black box's referent will cause the attempt to discover such a structure and mechanism to be discouraged.) The supressed premise is simply a generalization of the q -> r statement: when certain things are ignored, the attempt to discover them is discouraged. At this point, the discussion of content-type O will break off and that of content-type O will begin.

The concept-type O questions in this set have turned out to be a quite homogeneous lot. There is nothing inherent in the genus that makes it necessary that they should turn out this way, it just happens that they did. These questions tend to center on references, citations, quotations, allusions or mentions of some kind that the author makes somewhere in his text. While many possible patterns for questions of this concept-type exist, only one is used in this set. This general pattern that they all follow is exemplified by the question, "What is made of the fact that the water molecule was rejected by turn of the century energetists?" Here, the student is given to understand that the author has made some reference to a fact in the history of science. And what the student is asked to do is to state what use the author has made of this reference or, to put it another way, to specify the author's purpose in making it. Although this particular example displays some slight obliquity in the wording, virtually all of the rest of the concept-type O questions in this set are, if anything, more directly explicit.

The suggested answer to this question is, "The rejection of the water molecule model by the turn of the century energetists is part of a sort of reductio ad absurdum argument meant to show the foolishness of preferring a grey box model to a built-up one. The preference for grey or black box models can lead to the rejection of models that later prove their worth by gaining general acceptance." This answer attempts to accomplish two things: first, to supply the asked for purpose of the reference and second, to provide some insight into the manner by which this purpose is to be fulfilled. Since this one example suffices to display the peculiarities of concept-type O questions, their exposition will terminate here and that of concept-type P questions will follow.

Concept-type P questions deal with assumptions, conditions, premises or prerequisites of some kind or other. Typically, these turn out to be necessary assumptions upon which to base some theory or hypothesis or else prerequisites for the application of some method or procedure. Usually, the question asks either for the specification of the condition itself or perhaps for an explanation or reason as to why it exists or is necessary. As an example of the former, consider this question, "In order to apply the same general theory (classical statistical mechanics, for example) to several different model objects, what must be assumed about those model objects?" In this case, the given is the fact that the carrying out of a specified procedure is being considered, while the required is the assumption that must be made in order to carry it out. The suggested answer to the preceding question is, "In order to apply the same general theory, such as classical statistical mechanics, to several different model objects, it must be assumed that the elements of each of those model objects are related to each other in similar ways, in ways described by the general theory." This answer simply fulfills the requirement of the question by specifying the asked for assumption.

An example of the latter case is supplied by the question, "As long as the axiomatizability condition is not necessary to obtain a theoretical model, what is the reason for including it in the description of the process?" Here, the condition is not asked for; it, along with the fact that it is included although not necessary, is part of the given. What is asked for is an explanation of the anomaly wherein the condition is included in spite of the fact that it is not necessary to the specified process. The answer to this question, "Even though the axiomatizability condition is not necessary to obtain a theoretical model, it is necessary in order to give a quick and exact definition of the concept," poses no special problems. It merely supplies the required explanation which suggests that the condition, although not necessary, proves convenient. At this point, the discussion proceeds from the consideration of concept-type P questions to an explanation of concept-type Q questions. Concept-type Q questions are concerned with judgements of some kind or other. These judgements or evaluations may determine truth-values, utility values, or the presence or absence of some property or other. Their objects might be concepts, theories, objects, methods or procedures. As an example of the latter, it may prove helpful to reexamine the question, "What criteria were applied in order to determine the falsity of Ising's model object?" Here, the given is the fact of a judgement that determined the truth-value of a specified concept, while the criteria used in making that judgement is asked for. The suggested answer is, "The criteria that were applied in order to determine the falsity of Ising's model object were the relatively greater prestige of the general theory (statistical mechanics) and the principle that requires a theoretical model to represent every significant (relevant?) aspect of its referent if it is not to be considered false." This answer, quite directly and simply, provides the two criteria that the question asks for.

Another, perhaps less typical, case is exemplified by the question, "What does it mean to say that the game is not just to account for appearance at any price?" The given is not in itself the atypical component of this question. What is somewhat unusual is the slightly indirect manner in which the given judgement is presented. This presentation does not make it quite as obvious as do some of the other questions that a judgement is being asked about, nor that the object of the judgement is a method, a procedure, or to a considerable extent, a goal. The second and rather more obvious departure from the content of the ordinary concept-type Q question is the fact that a meaning is asked for. This suggests that what is wanted is some kind of interpretation, explanation or elaboration--an unpacking, as the cliché goes. The suggested answer to the question is, "To say that the game is not just to account for appearance at any price means that the attempt should be made not only to produce a mechanism that will adequately explain the end results of the referent, but come up with the actual mechanism that produces those results. This can be accomplished by showing some intermediate results that can be checked against those derived from the hypothetical mechanism."

This answer interprets the subject of the question as a kind of judgement-prescription. To categorize the question as a concept-type Q question rather than as a concept-type R question is to emphasize the judgement component at the expense of the prescription component. The question could have, justifiably, been placed in both categories; it is already shared by concept-type categories H and Q. The decision not to place it in category R as well represents a prior or even an ipso facto decision regarding the placement of the border line between thoroughness and over-meticulosity.

Consider now one more example, "Why should the one-dimensional representation of a tridimensional system be considered the most audacious of all model objects?" Again, the given in the question is the fact of a judgement; this time the judgement concerns the presence or absence of a specified quality in a specified concept. But what is asked for is a reason for that judgement--a justification. An answer is, "The one-dimensional representation of a tridimensional system should be considered the most audacious of all model objects because, although model objects inherently fall short of fully representing their referents, the one-dimensional model object's attempt to represent tridimensional referents can be considered particularly daring by virtue of the double handicap that it imposes upon itself by dispensing with two of the three dimensions that would ordinarily seem indispensable to the adequate representation of tridimensional referents." This answer provides the required explanation-justification in a straightforeward, unequivocal manner. The discussion of concept-type Q questions ends here and the consideration of concept-type R questions begins.

Concept-type R questions have to do with prescriptions, advice or suggestions. It may be the case either that the question asks for a prescription or that it requires an explanation or justification of a prescription already given. To exemplify the first of these cases, examine again the question, "What can be done to remedy the excessive coarseness and lack of economy characteristic of the description of the model wherein the paired inputs and outputs are tabulated?" A prescription is asked for by this question. Take another look at the answer, "To remedy the excessive coarseness and lack of economy characteristic of the description of the model wherein the paired inputs and outputs are tabulated, the ordered pairs can be implied by means of a rule rather than stated explicitly by means of a table." It supplies the required prescription in a straightforeward and obvious manner.

For an exemplification of the second case, look again at the question, "Why is an explicit statement of the semantic assumptions mandatory in the axiomatic reconstruction of a scientific theory?" In this case, the prescription is not asked for, but given. What is asked for is an explanatory justification of the given prescription. The suggested answer is, "An explicit statement of the semantic assumption is mandatory in the axiomatic reconstruction of a scientific theory because the same mathematical formulas will sometimes fit more than one referent. For example, the flow of water in a pipe can be represented by the same (or analogous) formulas as the flow of electricity in a wire. Thus, an explicit statement of the semantic assumption is needed to make sure that there is no confusion regarding which formula is being linked to which referent." This answer provides the explanatory justification for the prescription given by the question. And here the discussion proceeds from the consideration of concept-type R questions to the explanation of concept-type S questions.

The special province of concept-type S questions lies in the area of things gone wrong. Problems, errors, confusions or failures are the sorts of things to be found in this territory--the land of the blemished, the faulted, the defective. In some cases, the problem or error is given while an explanation or a response is asked for. In others the specification of the confusion or failure is expected. Or occasionally it may turn out that the fact of the error or confusion, masked in the question, shows up, perhaps unexpectedly, as the answer unfolds.

The first example is a reexamination of the question, "Why is it important not to confuse the model object with its referent?" The possibility as well as the nature of a confusion is specified as the given, while its significance or importance is what the question asks for. The suggested answer: "It is important not to confuse the model object with its referent because the same referent may be modeled by different model objects in different ways. Confusing the model object with its referent would, by obliterating or at least minimizing these differences, defeat the purpose of model objects--to discover ever 'truer' ways of representing reality." This answer attempts to demonstrate the significance of the confusion by means of a three step argument that assumes that several unstated intermediate steps can be supplied by the student who has become familiar with the text.

The opposite case: "What is the primary mistake that the black box philosopher makes?" Here the nature of the error must be specified by the answer. Only the fact of the mistake and its perpetrator is given. The suggested answer is, "The black box philosopher's primary mistake is his failure to recognize that the acquisition of knowledge as opposed to mere use requires the construction of built-up models as opposed to mere dark box models." Here, the mistake is specified and its general described as required by the question.

Consider the question, "Why should the modeling relation occur explicitly in any formulation of a scientific theory that takes care of the factual meaning of its symbols?" This question makes no obvious reference to an error or confusion at all. It simply asks why a theory should be formulated in a certain way. That is to say that it asks for a reason, an explanation. But look at the suggested answer, "The reason that the modeling relation should occur explicitly in any formulation of a scientific theory that takes care of the factual meaning of its symbols is to avoid any possible confusion between the model (theoretical) and the modeled (referent)." The required reason is supplied. But in the course of its development, it becomes clear that the original question implied a possible confusion to be avoided.

The fourth and last example is, "In section 10, it is stated that (1) semantical models are interpretations of formal systems that make all statements of the system true, (2) theoretical models (since their content is empirical) are never more that partially true so they cannot be semantical models, (3) the three empirical model objects described on page 112 are not always true, nonetheless (4) they constitute (or produce) semantical models." How is this possible?" This question suggests that something may be awry. But whether it presents a resolvable paradox or an unexplainable anomaly does become apparent solely from reading it. Is the inconsistency merely apparent or is it real? Here is the suggested answer, "This is not possible, it constitutes an unexplained contradiction. If semantical models are interpretations of formal systems that make all statements of the system true (1), and theoretical, hence empirical, models are never more than partially true (2), then it is manifestly impossible for them to constitute semantical models." The suggestion of the last sentence of the question that the set of statements is somehow consistent is revealed as misleading. The answer, in effect, rejects the question as unanswerable and answers in the negative an implied substitute question: "Is this possible?" Moreover, by implication, it goes some distance toward accusing the author of having made a mistake. The accusation could not be made in a more positive way because of the possibility that were the author present to defend himself he could come up with a satisfactory explanation of his apparent error. At this point, the explanation of concept-type S questions terminates and that of concept-type T questions begins.

The questions that are categorized as belonging to concept-type T involve choices or options of various kinds. At times the choice given in the question requires the answer either to explain the reasoning behind it or to specify the criteria that determined it. Other times a situation may be presented in the question which requires the answer to specify an appropriate response involving options or choices.

As an example of the former, consider the question, "Why would it not be preferable to construct a model object that could represent its referent in every aspect instead of in merely certain significant aspects?" In this case, the question, in effect, presents an (albeit negative) choice already made and asks for a justification of that choice. The suggested answer to this question is, "It would not be preferable to construct a model object that could represent its referent in every aspect instead of in merely certain significant aspects because the possession of sufficient knowledge to construct such a model object would render its construction redundant." This answer straightforewardly supplies the required justification.

The latter case is represented by this example, "What is the basic choice that the model constructor must make?" Here, a situation is presented and the outline of a choice-structure or a set of options is looked for. This requirement is satisfied by the suggested answer, "The basic choice that the model constructor must make is between superficial knowledge and deep knowledge. In the former case, the black box is adequate. But in the latter cause, a built-up conceptual model is required." This concludes explanation of concept-type T questions and, since they range from A to T, of the concept-types in general. Of the explanation of the whole categorical system into which the questions and answers are organized, all that remains is a brief review of the specific-content-constructs.

The specific-content-constructs differ from the rest of the categories that have been used to categorize the question and answer set in that are not organizational categories imposed from without, but rather salient concepts extracted from the body of the object-text itself. That is they are central concepts formulated by the author of the object-document and so their presence behind <u>every</u> question is at least implied whenever it is not specific. There are only four of these in the object-document used in this work: (1) referent, designated by the lower case letter "a," (2) model object, designated by letter "b," (3) theoretical model, designated by "c," and (4) general theory, by letter "d. "The referent is the bit of reality, the object, system or process that is modeled. The model object is the bare representation of the referent which has not as yet been organized deductively or mathematically. The theoretical model is the deductively and mathematically organized model model object. And a general theory is, as its name implies, a law or law-like theory of particularly wide application. These four concepts form a kind of concept-chain. The interrelations between these concepts in the chain form the subject matter of the object-document. With this review of the specific-content-concepts, the explanation of the the categories that organize the questions is finished. The next three chapters will be devoted to the presentation of the question and answers themselves.

CHAPTER VI

TASKS I AND II:
IDENTIFYING AND SPECIFYING

This chapter along with the next two are devoted to the exposition of the results, the end-product of the present work--a set of questions and answers arranged hierarchically according to the principles that have been set forth in the previous chapters. It has been explained that each question and answer unit begins with an identity line that locates it within the complete question and answer set, within the object-document, and within the conceptual hierarchy that forms the basis both for the formulation and for the organization of the question and answers.

One word about the form of the suggested answers to the questions. It will undoubtedly be noted that each answer, in effect, contains the total conceptual substance of the question that it is meant to accompany. This is not accidental. The background assumption operating here is that a tendency exists among students to disassociate answers from the questions that they were intended to answer. It is the purpose of the present mode of formulating the suggested answers to combat this tendency. Therefore, it is suggested that any practical application of either the question system or the principles behind it not dispense with this feature.

The questions and answers that follow in this chapter are numbered from 1 to 147. They are associated with the task-types I and II which involve the tasks of identification and specification. Here, then, are the questions and answers.

Task I

Question and Answer 1: page 92; line 1; type I, i, A, a.

What is a referent?

A referent (of a particular model object) is the object, process or bit of reality that is represented by that model object.

Q and A 2: page 92; line 1; type I, i, A, b.

What is a model object?

A model object is a schematic representation of an object or process, that is (97-18), a schematic conceptual representation of a thing or of a situation assumed to be actual or possible.

Q and A 3: page 97; line 17; type I, i, A, c.

What is a theoretical model?

A theoretical model is a hypothetico-deductive system concerning a model object.

Q and A 4: page 95; line 35; type I, i, A-C, a.

What is a factual referent?

A factual referent is a referent that is not merely abstract (formal), it possesses empirical content.

Q and A 5: page 93; line 2; type I, i, A-C, b.

What are non-realistic abstract situations?

Non-realistic abstract situations are, in effect, model objects in which only certain significant aspects of the referent are modeled. All other aspects of the referent are ignored.

Q and A 6: page 110; line 35; type I, i, A-C, c.

When is an interpretation of an abstract theory a semantical model?

An interpretation of an abstract theory is a semantical model whenever it makes the theory come out true in all circumstances.

Q and A 7: page 107; line 14; type I, iii, A, d.

What is a general theory?

A general theory is a theory (a hypothetico-deductive system) that has a particularly wide range of application by virtue of the fact that it contains only high level abstractions, which is to say that it has no specific empirical content.

Q and A 8: page 102; line 20; type I, iii, C, c.

What is a theoretical model of the behavior of a system?

A theoretical model of the behavior of a system is a set of statements, preferably mathematical formlulas, relating the exogenous variables I and O and the endogenous variables S of the system.

<u>Task II</u>:

<u>Q and A 9</u>: page 92; line 2; type II, i, A, a.

What is the object, mechanism, or process that a model object represents ?

The object, mechanism, or process that a model object represents is its referent.

<u>Q and A 10</u>: page 112; line 15; type II, i, A, a.

What is the referent of which the physical interpretation of the symbols; "s," "F(s)," "G(s,s');" and "H(s,s')," constitutes a model object?

The referent of which the physical interpretation of the symbols; "s," "F(s)," "G(s,s')," and "H(s,s');" constitute a model object is an electrical current at a given point in a circuit.

<u>Q and A 11</u>: page 112; line 15; type II, i, A, a.

What is the referent of which the sociological interpretation of the symbols; "s," "F(s)," "G(s,s')," and "H(s,s');" constitutes a model object?

The referent of which the sociological interpretation of the symbols; "s," "F(s)," "G(s,s')," and "G(s,s');" constitute a model object is the probability of migration taking place between one given country and another.

Q and A 12: page 103; line 22; type II, i, A-D, a.

What is the referent of the water molecule?

The referent of the water molecule is the composition of water, since it is this that the water molecule sets out to explain. In another sense, it can be said that the referent of the hypothetical or model water molecule is the "real" molecule that it is presumed to represent.

Q and A 13: page 106; line 24; type II, i, A-H, d.

What must be added to a general theory in order to obtain a theoretical model?

A model object must be added to a general theory in order to obtain a theoretical model.

Q and A 14: page 96; line 11; type II, i, B, a.

What do certain real valued functions that are given on a differentiable manifold represent?

Certain real valued functions that are given on a differentiable manifold represent properties of the referent.

Q and A 15: page 95; line 1; type II, i, B, b.

What feature of crude (simple) models frequently renders them more instructive than more complicated models?

The feature of crude (simple) models that frequently renders them more instructive than more complicated models is the exactness or precision of the solutions that they provide.

Q and A 16: page 110; line 15; type II, i, B, b.

What is the essential property of model objects that renders them useful?

The essential property of model objects that renders them useful is their ability to be expanded into hypothetico-deductive systems to form theoretical models.

Q and A 17: page 101; line 3; type II, i, B-C, c.

When it is said that there are many kinds of model objects and, consequently, of theoretical models, what property or properties account for these differences?

When it is said that there are many kinds of model objects and, consequently, of theoretical models, the property that accounts for the differences being talked about is the amount of explanatory mechanism that is postulated in each kind of model object.

Q and A 18: page 105; line 30; type II, i, B-H, d.

What characteristic of a given field of research diminishes the probability of finding general theories in that field?

A field of research that is likely to have few general theories is one that has produced mainly isolated bits of knowledge rather than unifying concepts.

Q and A 19: page 106; line 3; type II, i, B-H, d.

What kind of field of research can be expected to have many general theories?

A field of research that has produced many unifying concepts rather than mere isolated bits of knowledge can be expected to have many general theories.

Q and A 20: page 102; line 8; type II, i, C, b.

What kind of a model object is it that simply relates input and output by means of a rule.

A model object that simply relates input and output by means of a rule is a black box.

Q and A 21: page 102; line 13; type II, i, C, b.

What is a model called if it has an input and an output along with internal variables, but no explanatory mechanism?

A model that has an input and an output along with internal variables but no explanatory mechanism is called a grey box.

Q and A 22: page 102; line 17; type II, i, C, b.

What is a model called if its law can be represented by a formula relating the input, output, and the internal variables to each other?

If a model's law can be represented by a formula relating the input, output, and the internal variables to each other, it is called a grey box.

Q and A 23: page 102; line 36; type II, i, C, b.

What is a behavior model of a system?

A behavior model of a system is a model that attempts to relate significant phenomena to each other without attempting to explain them by means of any conjectured structure or mechanism. A model of this kind that makes no attempt to go beyond the phenomena is a black or grey box.

Q and A 24: page 95; line 32; type II, i, C, c.

What is a model object, if theoretical?

A model object, if theoretical, is not a model object at all. According to the terminology that has been employed hitherto, it is a theoretical model.

Q and A 25: page 105; line 9; type II, i, C-D-S, b.

Discussion of the variety of models that can be proposed for any given system serves to combat what erroneous notion?

Discussion of the variety of models that can be proposed for any given system serves to combat the mistaken notion that there is a one-to-one relation between referents and their models.

Q and A 26: page 103; line 1; type II, i, C-G, b.

What do black box models accomplish?

Black box models make it possible to condense the data and to predict the evolution of the system.

<u>Q and A 27</u>: page 105; line 16; type II, i, C-G, b.

If the primary goal of model construction were merely to make practical use of the referent, what kind of model would be most appropriate?

If the primary goal of model construction were merely to make practical use of the referent, the black or grey box model would probably prove most appropriate.

<u>Q and A 28</u>: page 105; line 16; type II, i, C-G, b.

In view of the fact that the goal of model construction is primarily the acquisition of theoretical knowledge, what kind of model object accords best with that goal?

In view of the fact that the goal of model construction is primarily the acquisition of theoretical knowledge, a built-up model object accords best with that goal.

<u>Q and A 29</u>: page 105; line 34; type II, i, C-G, b.

What can a built-up model object do that a black box model cannot?

A built-up model object can, and a black box model cannot, do the following: (1) A built-up model object can explain what takes place as opposed to merely noting that it does take place. (2) A built-up model object can predict new facts as opposed to merely making it possible to compute outputs for given inputs. (3) A built-up model object can provide knowledge that fits in with present knowledge as opposed to merely restating the behavior of observed systems.

Q and A 30: page 91; line 16; type II, i, CH, b.

What can be accomplished with a "black box?"

A black box can be expanded into a hypothetico-deductive system to produce a theoretical model.

Q and A 31: page 91; line 16; type II, 1. C-G-I, b.

What can be accomplished with a "black box?"

A black box can be expanded into a hypothetico-deductive system to produce a theoretical model.

Q and A 32: page 99; line 30; type II, i, C-G-O, b.

What is the point of citing the necklace, the sociogram, and the Watson-Crick model?

The point of citing the necklace, the sociogram, and the Watson-Crick model is to emphasize the fact that a variety of kinds of models is possible.

Q and A 33: page 100; line 1; type II, i, C-H, c.

How many ways are there of obtaining a theoretical model?

There are two ways of obtaining a theoretical model.

Q and A 34: page 100; line 1; type II, i, C-H, c.

What are the two ways of obtaining a theoretical model?

The two ways of obtaining a theoretical model are either to expand the model object or to embed it in a general theory.

Q and A 35: page 104; line 29; type II, i, C-H-Q, b.

How can the truth of the built-up models be checked?

The truth of the built-up models can be checked by attempting to infer behavior from them.

Q and A 36: page 101; line 4; type II, i, C-J, b.

What is the name given to a model object having no internal explanatory mechanism?

The name given to a model object having no internal explanatory mechanism is "black box."

Q and A 37: page 101; line 26; type II, i, C-J, b.

What is a model object that concerns itself only with accounting for the end results of the referent without attempting to explain how these results are obtained called?

A model object that concerns itself only with accounting for the end results of the referent without attempting to explain how these results are obtained is called a black box.

Q and A 38: page 111; line 12; type II, i, C-J, c.

What could a theoretical model that has been "confirmed" be termed to show that, to some extent (albeit inadequately), it fulfills the requirements of a semantical model?

In order to show that, to some extent, a "confirmed" theoretical model fulfills the requirements of a semantical model, it could be termed a "<u>quasi</u>model."

<u>Q and A 39</u>: page 107; line 25; type II, i, C-L, c.

What kind of theory is likely to be logically weak?

The kind of theory that is likely to be logically weak is a specific theory (or theoretical model).

<u>Q and A 40</u>: page 107; line 25; type II, i, C-L, d.

What kind of theory is likely to be logically strong?

The kind of theory that is likely to be logically strong is a general theory.

<u>Q and A 41</u>: page 109; line 7; type II, i, C-M, c.

What is the difference between deterministic models and probabilistic models?

The difference between deterministic models and probabilistic models is that deterministic models predict (or attempt to predict) what <u>will</u> occur under certain given conditions, whereas probabilistic models try to predict what <u>may</u> happen under given conditions while indicating in mathematical terms what the chances are that this or that event will or will not occur.

<u>Q and A 42</u>: page 105; line 27; type II, i, C-T, b.

What is the basic choice that the model constructor must make?

The basic choice that the model constructor must make is between superficial knowledge and deep knowledge. In the former case, the black box is adequate. But in the latter cause, a built-up conceptual model is required.

Q and A 43: page 91; line 5; type II, i, D, b.

What is the relation between the ball-and-spoke model of a molecule and the molecule itself?

The relation between the ball-and-spoke model of a molecule and the molecule itself is the relation that holds between a model object and its referent: the modeling relation.

Q and A 44: page 91; line 10; type II, i, D, b.

What is the relation between a continuum endowed with certain properties, such as compressibility and viscosity, and a fluid?

The relation between a continuum endowed with certain properties, such as compressibility and viscosity and fluid is the relation that holds between a model object and its referent: the modeling relation.

Q and A 45: page 91; line 13; type II, i, D, b.

What is the relation between a black box and a learning organism?

The relation between a black box and a learning organism is the relation that holds between a model object and its referent: the modeling relation.

Q and A 46: page 92; line 6; type II, i, D, b.

Of what is the relation between a contour map of a molecule and the molecule itself an example?

The relation between a contour map of a molecule and the molecule itself is the relation that holds between a model object and its referent: the modeling relation.

Q and A 47: page 92; line 7; type II, i, D, b.

Of what is the relation between the hamiltonian operator for a molecule and the molecule itself an example?

The relation between the hamiltonian operator for a molecule and the molecule itself is an example of the relation that holds between a model object and its referent: the modeling relation.

Q and A 48: page 92; line 10; type II, i, D, b.

Of what is the relation between the random net model of the brain and the brain itself an example?

The relation between the random net model of the brain and the brain itself is an example of the relation that holds between a model object and its referent: the modeling relation.

Q and A 49: page 92; line 24; type II, i, D, b.

What is the relation between a homogeneous set or equivalence class of mice and all the individuals of a given mice strain?

The relation between a homogeneous set or equivalence class of mice and all the individuals of a given mice strain is the relation that holds between a model object and its referent: the modeling relation.

Q and A 50: page 92; line 26; type II, i, D, b.

What is the relation between the ordered triple (*m*, *n*, *p*) and a collision of *m* cars having as a result *n* injured persons with a total damage of *p* dollars?

The relation between the ordered triple (*m*, *n*, *p*) and a collision of *m* cars having as a result *n* injured persons with a total damage of *p* dollars is the relation that holds between a model object and its referent: the modeling relation.

Q and A 51: page 93; line 23; type II, i, D, b.

What is the relation between a sketch of an animal population and the animal population itself?

The relation between a sketch of an animal population and the animal population itself is the relation between a model object and its referent: the modeling relation.

Q and A 52: page 96; line 3; type II, i, D, b.

What sorts of elements are related to other elements by the modeling relation?

The modeling relation relates constructs to facts.

Q and A 53: page 96; line 4; type II, i, D, b.

The modeling relates what to what?

The modeling relation relates model objects (and, by extension, theoretical models) to referents.

Q and A 54: page 93; line 5; type II, i, D, b.

What is the relation between a sketch of an animal population and the animal population itself?

The relation between a sketch of an animal population and the animal population itself is the relation that holds between a model object and its referent: the modeling relation.

Q and A 55: page 100; line 9; type II, i, D, b.

What is the relation between M and R?

The relation between M and R is the modeling relation. This relation can be expressed by saying that M is the model object that models R or that R is a referent that is represented by model object M.

Q and A 56: page 92; line 8; type II, i, D-E, b.

Of what is the relation between the Pseudo Areopagite's model of the celestial hierarchy and the celestial hierarchy itself an example?

The relation between the Pseudo Areopagite's model of the celestial hierarchy and the celestial hierarchy itself is an example of the relation that holds between a model object and its referent: the modeling relation.

Q and A 57: page 92; line 10; type II, i, D-E, b.

Of what is the relation between the random net model of the brain and the brain itself an example?

The relation between the random net model of the brain and the brain itself is an example of the relation that holds between a model object and its referent: the modeling relation.

Q and A 58: page 92; line 24; type II, i, D-E, b.

What is the relation between a homogeneous set or equivalence class of mice and all the individuals of a given mice strain?

The relation between a homogeneous set or equivalence class of mice and all the individuals of a given mice strain is the relation that holds between a model object and its referent: the modeling relation.

Q and A 59: page 92; line 26; type II, i, D-E, b

What is the relation between the ordered triple (*m*, *n*, *p*) and a collision of *m* cars having as a result *n* injured persons with a total damage of *p* dollars?

The relation between the ordered triple (*m*, *n*, *p*) and a collision of *m* cars having as a result *n* injured persons with a total damage of *p* dollars is the relation that holds between a model object and its referent: the modeling relation.

Q and A 60: page 93; line 10; type II, i, D-E, b.

What is the relation between Ising's model of matter in condensed states and matter in condensed states itself.

The relation between Ising's model of matter in condensed states and matter in condensed states itself is the relation that holds between a model object and its referent: the modeling relation.

Q and A 61: page 96; line 4; type II, i, D-E, b.

What relation is presumed to hold between the set of all of the first elements of the ordered pair (c,f) and the set of all of the second elements of the same ordered pair?

The relation that is presumed to hold between the set of all of the first elements of the ordered pair (c,f) and the set of all of the second elements of the same ordered pair is the relation that is presumed to hold between a model object and its referent: the modeling relation.

Q and A 62: page 92; line 6; type II, i, D-K, b.

Of what is the relation between a contour map of a molecule and the molecule itself an example?

The relation between a contour map of a molecule and the molecule itself is the relation that holds between a model object and its referent: the modeling relation.

Q and A 63: page 93; line 23; type II, i, D-K, b.

What is the relation between a sketch of an animal population and the animal population itself?

The relation between a sketch of an animal population and the animal population itself is the relation that holds between a model object and its referent: the modeling relation.

Q and A 64: page 92; line 33; type II, i, D-K, b.

What does the sign "§" designate?

The sign "§" designates the relation between a model object and its referent.

Q and A 65: page 112; line 15; type II, i, E, a.

What is the referent of which the physical interpretation of the symbols; "s," "F(s)," "G(s,s')" and "H(s,s')," constitutes a model object?

The referent of which the physical interpretation of the symbols; "s," "F(s)," "G(s,s')," and "H(s,s')" constitute a model object is an electrical current at a given point in a circuit.

Q and A 66: page 112; line 15; type II, i, E, a.

What is the referent of which the sociological interpretation of the symbols; "s," "F(s)," "G(s,s')," and "H(s,s')" constitutes a model object?

The referent of which the sociological interpretation of the symbols; "s," "F(s)," "G(s,s')," and "G(s,s')" constitute a model object is the probability of migration taking place between one given country and another.

Q and A 67: page 100; line 21; type II, H, E-G, b.

What do the mass point and the ball do?

The mass point and the ball--as examples of model objects--constitute alternate hypotheses that model a planet.

Q and A 68: page 103; line 20; type II, i, E-G, b.

What is the water molecule example supposed to show?

The water molecule example is supposed to show how conjecture and imagination are needed to explain the law of multiple proportions. Thus, this example is intended to exemplify the type of difficulty inherent in the attempt to disclose hidden structure and mechanism.

Q and A 69: page 109; line 2; type II, i, E-G, b.

What is the purpose of the examples of the mechanisms of electromagnetic propagation, of complex chemical reactions, and of biological evolution?

The purpose of the examples of the mechanisms of electromagnetic propagation, of complex chemical reactions, and of biological evolution is to combat the identification of the concepts of model and mechanism, that is, to show that the concept of model is broader than this identification would suggest, that there are models that are not mechanistic.

Q and A 70: page 109; line 27; type II, i, E-G, b.

What is the purpose of the quantum theory example?

The purpose of the quantum theory example is to show how a too narrow concept of model object (model objects are invariably analogues) has precipitated unnecessary confusion into an area of scientific investigation.

Q and A 71: page 110; line 8; type II, i, E-G, b.

What is the purpose of the coupled oscillators example?

The purpose of the coupled oscillators example is to reinforce the point that model objects, and hence theories, are solely sets of statements and never can include pictorial representations as integral parts.

Q and A 72: page 110; line 8; type II, i, E-G, b.

What is the purpose of the coupled oscillators example?

The purpose of the coupled oscillators example is to reinforce the point that model objects, and hence theories, are solely sets of statements and never can include pictorial representations as integral parts.

Q and A 73: page 100; line 19; type II, i, E-G, c.

What is the point of the example of the mass point or the ball as model objects for a planet?

The point of the example of the mass point or the ball as model objects for a planet is that model objects by themselves are not sufficient. Theoretical models must be constructed from the model objects if they are to prove useful.

<u>Q and A 74</u>: page 107; line 14; type II, i, E-G, c.

What is the purpose of the shell oscillation example?

The purpose of the shell oscillation example is the demonstration of the indispensability of theoretical models.

<u>Q and A 75</u>: page 106; line 13; type II, i, E-G, d.

What is the reason for bringing up the example of the model of a gas as a swarm of point particles connected by van der Waals forces?

The model of a gas as a swarm of point particle connected by van der Waals forces was brought up for the purpose of exemplifying the processes whereby the same model object can be fitted into different general theories thereby producing different theoretical models.

<u>Q and A 76</u>: page 108; line 10; type II, i, E-G, d.

What is the purpose of the example of the sun, the rotating ellipsoid or a mass point, and the theories of gravitation and of light?

The purpose of the example of the sun, the rotating ellipsoid or a mass point, and the theories of gravitation and of light is to illustrate what can and should be done when a theoretical model embedded in a general theory fails to conform to the facts.

Q and A 77: page 108; line 18; type II, i, E-G, d.

What is the purpose of the Dicke and Brans example?

The purpose of the Dicke and Brans example is to illustrate how the violation of the prescribed methodological rule has, in a real case, led theorists astray. Dicke and Brans violated this rule by proposing to discard Einstein's highly prestigious gravitation theory.

Q and A 78: page 109; line 15; type II, i, E-G, d.

What is the purpose of the example of the model of a machine out of kilter (model object) as a model of an unreliable fellow (referent) being embedded in the theory of Markovian machines (general theory)?

The purpose of the example of the model of a machine out of kilter as a model of an unreliable fellow being embedded (the model, not the fellow) in the theory of Markovian machines is to further broaden the concept of the model object by showing that not all model objects function as analogues by representing their referents indirectly in terms of another (usually more familiar) mechanism or process, but rather, that some model objects represent their referents by referring to them directly and literally.

<u>Q and A 79</u>: page 107; line 1; type II, i, E-G-H, d.

What is the purpose of the meteorologist example?

The purpose of the meteorologist example is to show how, in an "advanced area," theoretical models are typically produced by uniting the model objects with preexisting general theories rather than, as in the "backward areas," by building a hypothetico-deductive system around the model object.

<u>Q and A 80</u>: page 100; line 13; type II, i, E-J, c.

What is it that constitutes a theoretical model of a collection R of things?

What constitutes a theoretical model of a collection R of things is a hypothetico-deductive system with primitive base M.

<u>Q and A 81</u>: page 98; line 21; type II, i, E-L, c.

What is the central hypothesis of the McCulloch and Pitts model of the brain?

The central hypothesis of the McCulloch and Pitts model of the brain is that neurons fire only when the preceding neurons have fired during the preceding moment.

<u>Q and A 82</u>: page 93; line 25; type II, i, E-N-Q, b.

What criteria were applied in order to determine the falsity of Ising's model object?

The criteria that were applied in order to determine the falsity of Ising's model object were the relatively greater prestige of the general theory (statistical mechanics) and the principle that requires a theoretical model to represent every significant (relevant?) aspect of its referent if it is not to be considered false.

<u>Q and A 83</u>: page 107; line 25; type II, i, E-O, d.

What example of a logically strong theory has been cited?

The example of logically strong theory that has been cited (by implication, at least) is that of classical mechanics?

<u>Q and A 84</u>: page 107; line 14; type II, i, G, c.

What are the three chief functions of theoretical models?

The three chief functions of theoretical models are these: (1) the posing of specific theoretical problems, (2) the solution (explanation) of specific theoretical problems, and (3) the testing of proposed solutions (explanations).

<u>Q and A 85</u>: page 99; line 18; type II, i, G-H, b.

When a model object has been characterized in exact terms with the help of mathematical concepts, such as those of function and series, what has been accomplished?

When a model object has been characterized in exact terms with the help of mathematical concepts, such as those of function and series, a theoretical model has been constructed.

Q and A 86: page 105; line 16; type II, i, G-H, b.

What are the two principal goals of model construction?

The two principal goals of model construction are as follows: (1) to acquire theoretical understanding of the referent, (2) to make practical use of the referent.

Q and A 87: page 91; line 10; type II, i, G-H, d.

What can be accomplished with a continuum endowed with certain properties, such as compressibility and viscosity?

A continuum endowed with certain properties, such as compressibility and viscosity can be conjoined with (grafted onto) classical mechanics, general relativistic mechanics or some other general theory to produce a theoretical model of a fluid.

Q and A88: page 106; line 18; type II, i, G-H, d.

What is the purpose of assuming different particle shapes and different force laws while keeping classical mechanics throughout?

The purpose of assuming different particle shapes and different force laws while keeping classical mechanics throughout is to exemplify a method of applying different model objects to the same general theory to obtain different theoretical models.

Q and A 89: page 98; line 29; type II, i, G-H-O, b.

What is the purpose of the reference to the success of McCulloch and Pitts?

The purpose of the reference to the success of McCulloch and Pitts is to justify the method of starting with models objects that ignore certain significant aspects of their referents and then proceeding to complicate them when necessary.

Q and A 90: page 99; line 5; type II, i, G-H-O, c.

What is the point of listing some of the aspects of the referent that stochastic learning models ignore?

Some of the aspects of the referent that stochastic learning models ignore are listed in order to emphasize the concept of a model as a simplification or idealization.

Q and A 91: page 100; line 15; type II, i, G-H-P, c.

As long as the axiomatizability condition is not necessary to obtain a theoretical model, what is the reason for including it in the description of the process?

Even though the axiomatizability condition is not necessary to obtain a theoretical model, it is necessary in order to give a quick and exact definition of the concept.

Q and A 92: page 98; line 31; type II, i, G-I-O, c.

What does the introduction of Rapoport's stochastic models of the central nervous system accomplish?

The introduction of Rapoport's stochastic models of the central nervous system serves to justify the delayed complication of theoretical model--in this case, with the addition of the random factor.

Q and A 93: page 92; line 3; type II, i, G-K, b.

What is the point of saying that the representation may be pictorial, conceptual, figurative, semisymbolic, or symbolic?

The point of saying that the representation may be pictorial, conceptual, figurative, semisymbolic, or symbolic is that these are the modes of representation that model objects may make use of in performing their function of representing their referents.

Q and A 94: page 92; line 28; type II, i, G-K, c.

What is the importance of the mode of representation of model objects and theoretical models? The modes of representation of model objects and theoretical models are important only to the extent that they be necessary to enable the model objects or theoretical models to accomplish their purpose of representing reality. All of which is to say that their importance is not intrinsic at all; it is merely instrumental.

<u>Q and A 95</u>: page 100; line 26; type II, i, G-K, c.

What does the table do?

The table gives examples of model objects along with their corresponding referents and theoretical models.

<u>Q and A 96</u>: page 103; line 29; type II, i, G-M-R, b.

What is the importance of contrasting users with designers or scientists with engineers?

Users are contrasted with designers and scientists with engineers to show how the model's application should determine whether a dark box or a built-up model is chosen. Where mere use is contemplated, the dark box model is adequate, but where knowledge is desired, a built-up model is needed.

<u>Q and A 97</u>: page 95; line 13; type II, i, G-O, b.

What is the citation of Bush and Mosteller, and of Sternberg supposed to accomplish

The citing of Bush and Mosteller, and of Sternberg is supposed justify the procedure whereby crude (simple) models are utilized in the early stages of an investigation to point the way to the more complicated, hence realistic, models that are to be used in the later stages of the investigation.

<u>Q and A 98</u>: page 105; line 16; type II, i, G-O, b.

What is the purpose of the Pringle citation?

The purpose of the Pringle citation is to emphasize the dependence of the choice of model upon the goal of the investigator. If the goal is only to summarize data, a black box model is sufficient. But if further knowledge is sought, a built-up model is needed.

Q and A 99: page 94; line 30; type II, i, G-O, c.

What is the introduction of the papers by Kac, Uhlenbeck, and Hemmer; Dyson; and Kronig and Penney supposed to accomplish?

The introduction of the papers by Kac, Uhlenbeck, and Hemmer; Dyson; and Kronig and Penney is supposed to justify the use of crude theoretical models in the early stages of an investigation.

Q and A 100: page 103; line 25; type II, i, G-O-S, b.

What is made of the fact that the water molecule was rejected by turn of the century energetists?

The rejection of the water molecule model by the turn of the century energetists is part of a sort of reductio ad absurdum argument meant to show the foolishness of preferring a grey box model to a built-up one. The preference for grey or black box models can lead to the rejection of models that later prove their worth by gaining general acceptance.

Q and A 101: page 107; line 35; type II, i, G-Q, c.

What is the object of assessing blame in case a theory fails?

The object of assessing blame in case a theory fails is to know what to modify or discard in order to come up with a viable theory.

Q and A 102: page 91; line 11; type II, i, H, c.

In what two ways can theoretical models be obtained?

Theoretical models can be obtained either by grafting model objects onto general theories or by expanding model objects to hypothetico-deductive systems.

Q and A 103: page 105; line 37; type II, i, H, c.

In a field of research like contemporary mathematical sociology which has tended to produce isolated bits of knowledge rather than unifying concepts, how are theoretical models typically constructed?

In a field of research like contemporary mathematical sociology which has tended to produce isolated bits of knowledge rather than unifying concepts, theoretical models are typically constructed by by building them around model objects. This is usually done by expanding the model into a mathematically oriented hypothetico-deductive system,

Q and A 104: page 106; line 3; type II, i, H, c.

In a field of research like atomic and molecular physics which has tended to produce unifying concepts rather than mere isolated bits of knowledge, how are theoretical models typically constructed?

In a field of research like atomic and molecular physics which has tended to produce unifying concepts rather than mere isolated bits of knowledge, theoretical models are typically produced by fitting model objects to existing general theories. That is to say that the model object is attached to the relevant part of the mathematical hypothetico-deductive apparatus of the general theory.

Q and A 105: page 106; line 29; type II, i, H, c.

How are theoretical models usually obtained in the developing areas of science?

In the developing areas of science, theoretical models are usually obtained by starting with the model object and elaborating a set of formulas that define it.

Q and A 106: page 107; line 8; type II, i, H, c.

What manner of producing theoretical models do psychologists and sociologists have at their disposal?

The manner of producing theoretical models that psychologists and sociologists have at their disposal involves building hypothetico-deductive systems around model objects.

Q and A 107: page 91; line 11; type II, i, H, d.

What process unites a model object with a general theory?

The process that unites a model object with a general theory is the process of "grafting on."

Q and A 108: page 97; line 26; type II, i, H, d.

What can be done with a general theory in conjunction with a model object?

A general theory can be applied to a model object to produce a theoretical model.

Q and A 109: page 106; line 20; type II, i, H, d.

In what two ways can multiple theoretical models be generated?

Multiple theoretical models can be generated either by embedding the same model object into different general theories or by grafting different model objects onto the same general theory.

Q and A 110: page 106; line 25; type II, i, H, d.

How is a model object added to a general theory in order to produce a theoretical model?

A model object is added to a general theory in order to produce a theoretical model by adding to the general theory a set of subsidiary hypotheses that characterize or define the model object

Q and A 111: page 107; line 25; type II, i, H, d.

How are general theories tested?

General theories are tested by testing the theoretical models that are produced from them by joining model objects to them.

Q and A 112: page 93; line 33; type II, i, H-I, b.

What procedure do Onsager's good results justify?

The procedure that Onsager's good results justify is that of making simple model objects to start and complicating them later.

Q and A 113: page 107; line 19; type II, i, H-I, b.

What is the result of specifying the boundary and initial conditions, the mass and stress distributions, and the external forces for the oscillation of a shell?

The result of specifying the boundary and initial conditions, the mass and stress distributions, and the external forces for the oscillation of a shell is a model object.

Q and A 114: page 97; line 9; type II, i, H-I, c.

What must done with a model object if it is to become useful?

If a model object is to become useful, it must be converted into a theoretical model.

Q and A 115: page 98; line 8; type II, i, H-I, c.

What can be accomplished by complicating the Bloch model?

By complicating the Bloch model, more properties of the crystal can be explained.

Q and A 116: page 98; line 10; type II, i, H-I, c.

What must be done in order to render the theoretical model capable of representing more traits?

To render the theoretical model capable of representing more traits, it must be made more complicated.

Q and A 117: page 104; line 19; type II, i, H-I, c.

What is the result of adding the constitutive equations of the oscillation of a shell to the model object of this referent?

The result of adding the constitutive equations of the oscillation of a shell to the model object of this referent is a theoretical model of it.

Q and A 118: page 97; line 25; type II, i, H-I, d.

How was the Bloch model of a crystal obtained?

The Bloch model of a crystal was obtained by applying wave mechanics (a general theory) to a simple model of a crystal (a model object).

Q and A 119: page 109; line 19; type II, i, H-I, d.

What would be the expected result of embedding the model of a machine out of kilter (model object) in the theory of Markovian machines (general theory)?

The expected result of embedding the model of a machine out of kilter in the theory of Markovian machines would be the production of a theoretical model.

Q and A 120: page 99; line 2; type II, i, H-M, d.

What difference between the advanced and the backward sciences makes it necessary to obtain theoretical models differently in each?

The difference between the advanced and the backward sciences that makes it necessary to obtain theoretical models differently in each is the relatively plentiful supply of general theories in the one as opposed to their relative paucity in the other.

Q and A 121: page 99; line 22; type II, i, H-M, d.

What is the difference in the way that theoretical models are typically obtained in the advanced sciences as opposed to the way that they are obtained in the backward sciences?

In the advanced sciences, theoretical models are typically obtained by embedding model objects in one or another of the relatively plentiful general theories that are to be found there. In the backward sciences, however, theoretical models are usually obtained by expanding the model objects into mathematically explicit hypothetico-deductive systems; since there, general theories are typically scarce.

Q and A 122: page 100; line 1; type II, i, H-P, c.

What is the prerequisite (if any) for obtaining a theoretical model?

The prerequisite for obtaining a theoretical model is a model object.

Q and A 123: page 107; line 8; type II, i, H-P, d.

What is the enviable position that the psychologists and sociologists have not, so far, attained?

The enviable position that the psychologists and sociologists have not, so far, attained is that of being able to count on general theories to attach their model objects to in order to produce theoretical models.

Q and A 124: page 108; line 15; type II, i, H-P, d.

Under what conditions should the model object be modified or discarded in favor of the general theory?

The model object should be modified or discarded in favor of the general theory when the general theory has had a long and distinguished career or then the model object is obviously much too coarse.

Q and A 125: page 108; line 20; type II, i, H-P, d.

Under what conditions should the general theory be modified or discarded in favor of the model object?

The general theory should be modified or discarded in favor of the model object if it has failed in the past or if it is very young and cannot be assigned a truth value.

Q and A 126: page 108; line 23; type II, i, H-Q, c.

What three steps are involved in the verification of theoretical models?

The three steps involved in the verification of theoretical models are these: (1) the building of several model objects,(2) the joining of these model objects to the generic theory to produce theoretical models, a (3) the testing of these theoretical models to find out if they agree with the empirical facts.

Q and A 127: page 108; line 1; type II, i, H-Q-S, d.

If a theoretical model not associated with a general theory fails to conform to the facts, what can be done?

If a theoretical model not associated with a general theory fails to conform to the facts, the theoretical model must be modified or replaced. This involves trying out other theoretical models.

Q and A 128: page 107; line 35; type II, i, H-Q-T, d.

In case that a theory fails, what options are available with respect to blame assessment?

In case that a theory fails, the options that are available with respect to blame assessment are either to blame the theoretical model, and hence the model object, or to blame the general theory.

Q and A 129: page 103; line 13; type II, i, H-S, b.

What difficulty is inherent in most attempts to disclose the inner structure and mechanism of a system?

The difficulty inherent in most attempts to disclose the inner structure and and mechanism of a system lies in the fact that such structures and mechanisms are usually hidden and cannot be seen. Thus, they must be conjectured or imagined.

Q and A 130: page 108; line 5; type II, i, H-S-T, d.

If a theoretical model that is associated with a general theory fails to conform to the facts, what can be done?

If a theoretical model that is associated with a general theory fails to conform to the facts, either the theoretical model or the general theory can be modified or replaced.

Q and A 131: page 92; line 2; type II, i, J, b.

What is the object, mechanism, or process that a model object represents called?

The object, mechanism, or process that a model object represents is called its referent.

Q and A 132: page 97; line 20; type II, i, J, c.

What is a specific theory?

A specific theory is a theoretical model.

Q and A 133: page 111; line 33; type II, i, J-L, c.

What is the set of statements, F1 through F4?

The set of statements, F1 through F4, is the interpreted system that has been obtained by applying the interpretation; "the capital letters are sets or functions, 'R' is the real line, 'O' is the arithmetic product, etc.;" to the system of statement forms A1 through A5.

Q and A 134: page 100; line 9; type II, i, K, a.

What does R represent?

R represents a referent.

Q and A 135: page 100; line 8; type II, i, K, b.

What does M represent?

M represents a model object.

Q and A 136: page 101; line 37; type II, i, K-R, b.

What can be done to remedy the excessive coarseness and lack of economy characteristic of the description of the model wherein the paired inputs and outputs are tabulated?

To remedy the excessive coarseness and lack of economy characteristic of the description of the model wherein the paired inputs and outputs are tabulated, the ordered pairs can be implied by means of a rule rather than stated explicitly by means of a table.

Q and A 137: page 93; line 25; type II, i, N-Q, c.

To arrive at the diagnostic "false" for Ising's model what rule or principle was applied?

To arrive at the diagnostic "false" for Ising's model, the principle that requires a theoretical model to represent every significant (relevant?) aspect of its referent if it is not to be considered false was applied.

Q and A 138: page 93; line 27; type II, i, N-Q, d.

What criterion was applied in order to determine the falsity of Ising's model object?

The criterion that was applied in order to determine the falsity of Ising's model object was the relatively greater prestige of the general theory (statistical mechanics).

Q and A 139: page 104; line 7; type II, i, N-S, b.

What is the primary mistake that the black box philosopher makes?

The black box philosopher's primary mistake is his failure to recognize that the acquisition of knowledge as opposed to mere use requires the construction of built-up models as opposed to mere dark box models.

Q and A 140: page 105; line 13; type II, i, N-T, b.

What are the gross criteria that determine the choice from among the variety of models available to represent any given referent?

The gross criteria that determine the choice from among the variety of models available to represent any given referent are the following: (1) the nature of the referent, (2) the goal of the investigator.

Q and A 141: page 93; line 27; type II, i, Q-T, c.

What options are there for placing the blame in case a theoretical model proves false?.

In case a theoretical model proves false, there are usually two options for placing the blame: (1) It can be determined that the model object is at fault. (2) It can be determined that the general theory is at fault.

Q and A 142: page 104; line 14; type II, ii, C-G-I b

Does the black box model have any use in the process of scientific inquiry?

Yes. The black box model does have a use in the process of scientific inquiry. But this use occurs primarily during the early stages of scientific investigation.

Q and A 143: page 100; line 14; type II, ii, H-I-P, c.

Does the satisfaction of the axiomatizability condition guarantee the production of a theoretical model as long as the other conditions are as described.

Yes. The satisfaction of the axiomatizability condition does guarantee the production of a theoretical model as long as the other conditions are as described.

Q and A 144: page 100; line 14; type II, ii, H-P, c.

Would it be possible to obtain a theoretical model of R without satisfying the axiomatizability condition?

Yes. It would be possible to obtain a theoretical model of R without satisfying the axiomatizability condition.

Q and A 145: page 100; line 1; type II, ii, H-P, d.

Is a general theory a prerequisite for obtaining a theoretical model?

No. A general theory is not a prerequisite for obtaining a theoretical model. It is quite possible to obtain a theoretical model even though there is no general theory on the horizon.

Q and A 146: page 104 line 16 type II, iii, C-G-I, b.

If one of the aims of research were to be instantaneously and universally realized, what would be the effect on all black boxes?

If one of the aims of research were to be instantaneously and universally realized, all black boxes would be converted into built-up models. Since one of the aims of research is to throw further light into every box, the accomplishment of this aim would change all black boxes into built-up models or, at least, into grey boxes.

Q and A 147: page 104 line 14 type II, iii, C-I-N, b.

What would be the likely result of the universal application of the black boxist philosophy?

The likely result of the universal application of the black boxist philosophy would be the immediate drying up of the sources of scientific knowledge and, consequently, an eventual halt to scientific progress.

This concludes the presentation of the questions and answers that are associated with the task-types I and II. The questions that have been presented in this chapter involve the tasks of identification and specification.

In the next chapter, questions associated with task-types III, IV, V, and VI will be presented. Those questions involve the tasks of description, classification, comparison, and interpretation.

CHAPTER VII

TASKS III, IV, V, AND VI:

DESCRIBING, CLASSIFYING, COMPARING AND INTERPRETING

The questions and answers associated with task-types I and II involving the tasks of identification and specification have been presented in the preceding chapter. Here the presentation of the questions and answers continues with the task-types III, IV, V, and VI involving the tasks of description, classification, comparison, and interpretation. These questions and answers, numbered from 148 to 275 follow immediately.

Task III

Q and A 148: page 95; line 17; type III, i, C, b.

What is a more or less schematic model object?

A more or less schematic model object is a model object that in some way represents its referent but does it rather crudely--leaving out many significant aspects of the referent.

Q and A 149: page 103; line 6; type III, i, C, b.

What kind of a model is a built-up model of a system?

A built-up model of a system is a model that shows the inner structure and the mechanism of the system.

Q and A 150: page 103; line 3; type III, i, C-H, b.

What will a black box model not do?

A black box model will not explain the behavior of a system, nor will it provide the kind of knowledge that can be related to scientific knowledge in general.

Q and A 151: page 96; line 17; type III, i, D-E, c.

What is the logical form of the formula for the total mass of cell r?

The logical form of the formula for the total mass of cell r is that of a conditional whose antecedent is a statement of the modeling relation and whose consequent is a statement about the total mass of cell r.

Q and A 152: page 93; line 21; type III, i, H-P, d.

In order to apply the same general theory (classical statistical mechanics, for example) to several different model objects, what must be assumed about those model objects?

In order to apply the same general theory, such as classical statistical mechanics, to several different model objects, it must be assumed that the elements of each of those model objects are related to each other in similar ways, in ways described by the general theory.

Q and A 153: page 104; line 9; type III, i, N-S, b.

What is the black boxist's attitude toward mind and brain.

The black boxist would have us consider only the input and output of the mind and brain without any inquiry into the kinds of structure and mechanism that convert the one into the other.

Task IV

Q and A 154: page 91; line 14; type IV, i, A-C, d.

What is a "black box?"

A black box is a kind of a kind of model object in which no mechanism is displayed; only an input and output are provided.

Q and A 155: page 100; line 11; type IV, i, A-L, b.

What do any consistent set of conditions (postulates) specifying the structure (mathematical nature) of the n primitive concepts of Q, as well as their factual meaning, constitute?

Any consistent set of conditions specifying the structure of the n primitive concepts of Q, as well as their factual meaning, is a theoretical model of R.

Q and A 156: page 98; line 15; type IV, i, C-E, b.

What kind of model object is the McCulloch and Pitts brain model?

The McCulloch and Pitts brain model is an example of a grey box model.

Q and A 157: page 93; line 10; type IV, i, D, b.

What is the relation between Ising's model of matter in condensed states and matter in condensed states itself.

The relation between Ising's model of matter in condensed states and matter in condensed states itself is the relation that holds between a model object and its referent: the modeling relation.

Q and A 158: page 91; line 10; type IV, i, E, a.

What is a fluid?

A fluid is an example of a referent.

Q and A 159: page 91; line 13; type IV, i, E, a.

What is a "learning organism?"

A "learning organism" is an example of a referent.

Q and A 160: page 92; line 9; type IV, i, E, a.

What is the celestial hierarchy?

The celestial hierarchy is an example of a referent.

Q and A 161: page 92; line 10; type IV, i, E, a.

What is the brain?

The brain is an example of a referent.

Q and A 162: page 92; line 10; type IV, i, E, a.

What is the random net model of the brain?

The random net model of the brain is an example of a model object.

Q and A 163: page 92; line 21; type IV, i, E, a.

What do all the individuals of a given mice strain constitute?

All the individuals of a given mice strain constitute an example of a referent.

<u>Q and A 164</u>: page 92; line 26; type IV, i, E, a.

What is a collision of <u>m</u> cars having as a result <u>n</u> injured persons with a total damage of <u>p</u> dollars?

A collision of <u>m</u> cars having as a result <u>n</u> injured persons with a total damage of <u>p</u> dollars is an example of a referent.

<u>Q and A 165</u>: page 93; line 10; type IV, i, E, a.

What is matter in condensed states?

Matter in condensed states is an example of a referent.

<u>Q and A 166</u>: page 93; line 23; type IV, i, E, a.

What is an animal population?

An animal population is an example of a referent.

<u>Q and A 167</u>: page 94; line 23; type IV, i, E, a.

What is a gas?

A gas is an example of a referent.

<u>Q and A 168</u>: page 94; line 30; type IV, i, E, a.

What is the glass structure?

The glass structure is an example of a referent.

<u>Q and A 169</u>: page 95; line 22; type IV, i, E, a.

What is R?

R is an example of a referent (the set of individuals to be represented).

Q and A 170: page 96; line 4; type IV, i, E, a.

What is the set of all of the second elements of the ordered pair (c,f)?

The set of all of the second elements of the ordered pair (c,f) is an example of a referent›

Q and A 171: page 96; line 9; type IV, i, E, a.

What is a cell?

A cell is an example of a referent.

Q and A 172: page 97; line 7; type IV, i, E, a.

What is a liquid?

A liquid is an example of a referent.

Q and A 173: page 97; line 7; type IV, i, E, a.

What is a brain?

A brain is an example of a referent.

Q and A 174: page 97; line 11; type IV, i, E, a.

What is a gas?

A gas is an example of a referent.

Q and A 175: page 97; line 26; type IV, i, E, a.

What is a crystal?

A crystal is an example of a referent.

Q and A 176: page 98; line 15; type IV, i, E, a.

What is the brain?

The brain is an example of a referent.

Q and A 177: page 99; line 2; type IV, i, E, a.

What is animal behavior?

Animal behavior is an example of a referent.

Q and A 178: page 99; line 33; type IV, i, E, a.

What sort of thing does some-of-the-relations-among-the-individuals-in-a-community constitute?

Some-of-the-relations-among-the-individuals-in-a-community constitutes an example of a referent.

Q and A 179: page 100; line 5; type IV, i, E, a.

What is a cell?

A cell is an example of a referent.

Q and A 180: page 100; line 21; type IV, i, E, a.

What is a planet?

A planet is an example of a referent.

Q and A 181: page 106; line 7; type IV, i, E, a.

What is a carbon atom?

A carbon atom is an example of a referent.

Q and A 182: page 106; line 13; type IV, i, E, a.

What is a gas?

A gas is an example of a referent.

Q and A 183: page 107; line 4; type IV, i, E, a.

What is the real atmosphere?

The real atmosphere is an example of a referent.

Q and A 184: page 107; line 19; type IV, i, E, a.

What is the oscillation of a shell?

The oscillation of shell is an example of a referent.

Q and A 185: page 108; line 10; type IV, i, E, a.

What is the sum (along with its optical and gravitational manifestations)?

The sum (along with its optical and gravitational manifestations) is an example of a referent.

Q and A 186: page 109; line 2; type IV, i, E, a.

What are the mechanisms of electromagnetic propagation, of complex chemical reactions, and of biological evolution?

The mechanisms of electromagnetic propagation, of complex chemical reactions, and of biological evolution are example of referents for which model objects and then theoretical models can be hypothesized or constructed.

Q and A 187: page 109; line 16; type IV, i, E, a.

What is an unreliable person?

An unreliable person is an example of a referent.

Q and A 188: page 110; line 4; type IV, i, E, a.

What is the motion of a set of coupled oscillators?

The motion of a set of coupled oscillators is an example of a referent.

Q and A 189: page 91; line 10; type IV, i, E, b.

What is a continuum endowed with certain properties, such as compressibility and viscosity?

A continuum endowed with certain properties, such as compressibility and viscosity is an example of a model object.

Q and A 190: page 92; line 6; type IV, i, E, b.

What is a contour map of a molecule?

A contour map of a molecule is an example of a model object.

Q and A 191: page 92; line 7; type IV, i, E, b.

What is the hamiltonian operator?

The hamiltonian operator is an example of a model object.

Q and A 192: page 92; line 8; type IV, i, E, b.

What is the Pseudo Areopagite's model of the celestial hierarchy?

The Pseudo Areopagite's model of the celestial hierarchy is an example of a model object.

Q and A 193: page 92; line 24; type IV, i, E, b.

What is a homogeneous set or equivalence class (of mice)?

A homogeneous set or equivalence class (of mice) is an example of model object.

Q and A 194: page 92; line 28; type IV, i, E, b.

What is the ordered triple (*m*, *n*, *p*)?

The ordered triple (*m*, *n*, *p*) is an example of a model object.

Q and A 195: page 93; line 10; type IV, i, E, b.

What is Ising's model of matter in condensed states?

Ising's model of matter in condensed states is an example of a model object.

Q and A 196: page 93; line 23; type IV, i, E, b.

What is a sketch of an animal population?

A sketch of an animal population is an example of a model object.

Q and A 197: page 95; line 23; type IV, i, E, b.

What do the homogeneous subsets S constitute?

The homogeneous subsets S constitute an example of a model object.

Q and A 198: page 95; line 24; type IV, i, E, b.

What is each member s?

Each member s is an element of set S which, in turn, constitutes an example of a model object.

Q and A 199: page 96; line 4; type IV, i, E, b.

What is the set of all of the first elements of the ordered pair (c,f)?

The set of all of the first elements of the ordered pair (c,f) is an example of a model object.

Q and A 200: page 96; line 10; type IV, i, E, b.

What is a differentiable manifold?

A differentiable manifold is an example of a model object.

Q and A 201: page 97; line 7; type IV, i, E, b.

What is a molecular lattice?

A molecular lattice is an example of a model object.

Q and A 202: page 97; line 8; type IV, i, E, b.

What is a neuron net?

A neuron net is an example of a model object.

Q and A 203: page 97; line 26; type IV, i, E, b.

What is a simple model of the crystal?

A simple model of the crystal is an example of a model object.

Q and A 204: page 98; line 15; type IV, i, E, b.

What is the McCulloch and Pitts brain model?

The McCulloch and Pitts brain model is an example of a model object.

Q and A 205: page 99; line 32; type IV, i, E, b.

What is a chain of multicolored beads?

A chain of multicolored beads is an example of a model object.

Q and A 206: page 99; line 33; type IV, i, E, b.

What is a sociogram?

A sociogram is an example of a model object.

Q and A 207: page 99; line 35; type IV, i, E, b.

What sort of thing is the Watson-Crick model of DNA?

The Watson-Crick model of DNA is an example of a model object.

Q and A 208: page 100; line 5; type IV, i, E, b.

What is a model cell?

A model cell is an example of a model object.

Q and A 209: page 100; line 22; type IV, i, E, b.

What is a mass point?

A mass point is an example of a model object.

Q and A 210: page 100; line 22; type IV, i, E, b.

What is a ball?

A ball is an example of a model object.

Q and A 211: page 103; line 22; type IV, i, E, b.

What is a water molecule?

A water molecule is an example of a model object.

Q and A 212: page 106; line 6; type IV, i, E, b.

What is a hamiltonian operator?

A hamiltonian operator is an example of a model object.

Q and A 213: page 106; line 14; type IV, i, E, b.

What is a swarm of point particles connected by van der Waals forces?

A swarm of point particles connected by van der Waals forces is an example of a model object.

Q and A 214: page 108; line 10; type IV, i, E, b.

What is a rotating ellipsoid or a mass point?

A rotating ellipsoid or a mass point is an example of a model object.

Q and A 215: page 109; line 16; type IV, i, E, b.

What is a vending machine out of order?

A vending machine out of order is an example of a model object. The unreliable person would, of course, be the referent of this model object.

<u>Q and A 216</u>: page 110; line 3; type IV, i, E, b.

What are the alternative representations of the motion of a set of coupled oscillators?

The alternative representations of the motion of a set of coupled oscillators are examples of model objects.

<u>Q and A 217</u>: page 110; line 6; type IV, i, E, b.

What are the symbolic diagrams that correspond to the alternative representations of the motion of the set of coupled oscillators?

The symbolic diagrams that correspond to the alternative representations of the motion of the set of coupled oscillators are examples of heuristic devices (the alternative representations) more intelligible while remaining merely adjuncts to, and not parts of, those model objects.

<u>Q and A 218</u>: page 111; line 33; type IV, i, E, b.

What is the series of statements; "the capital letters are sets or functions, 'R' is the real line, 'O' is the arithmetic product, etc.?"

The series of statements; "the capital letters are sets or functions, 'R' is the real line, 'O' is the arithmetic product, etc." is an interpretation for the system of signs A1 through A5.

Q and A 219: page 112; line 15; type IV, i, E, b.

What do the physical and sociological interpretations of the symbols; "s," "F(s)," "G(s,s')," and "H(s,s')" constitute?

The physical and sociological interpretations of the symbols; "s," "F(s)," "G(s,s')," and "H(s,s')" constitute examples of model objects.

Q and A 220: page 112; line 26; type IV, i, E, b.

What does the set of entities; "the set of bodies," "the temperature," "the quantity of heat per unit mass," and "the specific heat at constant volume" constitute?

The set of entities; "the set of bodies," "the temperature," "the quantity of heat per unit mass," and "the specific heat at constant volume" constitutes an example of a model object.

Q and A 221: page 94; line 23; type IV, i, E, c.

What is a linear model of a gas?

A linear model of a gas is an example of a theoretical model.

Q and A 222: page 94; line 29; type IV, i, E, c.

What is Dyson's random chain?

Dyson's random chain is an example of a theoretical model.

Q and A 223: page 95; line 19; type IV, i, E, c.

What is M?

M is an example of a theoretical model.

Q and A 224: page 96; line 10; type IV, i, E, c.

What is a differentiable manifold on which certain real valued functions are given?

A differentiable manifold on which certain real valued functions are given is an example of theoretical model.

Q and A 225: page 97; line 10; type IV, i, E, c.

What is the kinetic gas theory?

The kinetic gas theory is an example of a theoretical model.

Q and A 226: page 98; line 5; type IV, i, E, c.

What is the Bloch model of a crystal?

The Bloch model of a crystal is an example of a theoretical model.

Q and A 227: page 98; line 30; type IV, i, E, c.

What are stochastic models of the central nervous system?

Stochastic models of the central nervous system are examples of theoretical models.

Q and A 228: page 99; line 3; type IV, i, E, c.

What are stochastic learning models?

Stochastic learning models are examples of theoretical models.

<u>Q and A 229</u>: page 111; line 17; type IV, i, E, c.

What is the system of signs: A1 through A5?

The system of signs, A1 through A5, is an example of a purely formal (and uninterpreted) theory, that is to say, a related series of statement forms.

<u>Q and A 230</u>: page 111; line 33; type IV, i, E, c.

Does the interpreted system, F1 through F4, constitute an example of a theoretical model?

No. The interpreted system, F1 through F4, does not constitute an example of a theoretical model because, although it has now been interpreted, the interpretation is mathematical not factual. Thus, it still includes no empirical content.

<u>Q and A 231</u>: page 91; line 10; type IV, i, E, d.

What is "classical mechanics?"

Classical mechanics is an example of a general theory.

<u>Q and A 232</u>: page 91; line 13; type IV, i, E, d.

What is "general relativistic mechanics?"

General relativistic mechanics is an example of a general theory.

<u>Q and A 233</u>: page 93; line 19; type IV, i, E, d.

What is classical statistical mechanics?

Classical statistical mechanics is an example of a general theory.

Q and A 234: page 97; line 12; type IV, i, E, d.

What is general statistical mechanics?

General statistical mechanics is an example of a general theory.

Q and A 235: page 97; line 12; type IV, i, E, d.

What is thermodynamics?

Thermodynamics is an example of a general theory.

Q and A 236: page 97; line 14; type IV, i, E, d.

What is general graph theory?

General graph theory is an example of a general theory.

Q and A 237: page 97; line 24; type IV, i, E, d.

What is the current theory of the solid state?

The current theory of the solid state is an example of a theoretical model.

Q and A 238: page 97; line 25; type IV, i, E, d.

What is wave mechanics?

Wave mechanics is an example of a general theory.

Q and A 239: page 97; line 33; type IV, i, E, d.

What is quantum mechanics?

Quantum mechanics is an example of a general theory.

Q and A 240: page 106; line 15; type IV, i, E, d.

What is relativistic particle mechanics?

Relativistic particle mechanics is an example of a general theory.

<u>Q and A 241</u>: page 106; line 15; type IV, i, E, d.

What is classical particle mechanics?

Classical particle mechanics is an example of a general theory.

<u>Q and A 242</u>: page 106; line 37; type IV, i, E, d.

What are hydrodynamics and thermodynamics?

Hydrodynamics and thermodynamics are examples of general theories.

<u>Q and A 243</u>: page 108; line 13; type IV, i, E, d.

What are the theories of gravitation and of light?

The theories of gravitation and of light are examples of general theories.

<u>Q and A 244</u>: page 109; line 22; type IV, i, E, d.

What is the theory of Markovian machines?

The theory of Markovian machines is an example of a general theory.

<u>Q and A 245</u>: page 110; line 37; type IV, ii, A, c.

Can metascientific theories ever qualify as semantic models?

No. Metascientific theories cannot ever qualify as semantic models.

<u>Q and A 246</u>: page 111; line 7; type IV, ii, A, c.

Would it be possible for a semantical model to qualify as a model in the metascientific sense?

Yes, it would be possible for a semantical model to qualify as a model in the metascientific sense.

Q and A 247: page 111; line 7; type IV, ii, A-C, c.

Do all semantical models qualify as metascientific models?

No. Not all semantical models qualify as metascientific models.

Q and A 248: page 112; line 26; type IV, ii, A-C, c.

Does the set of entities: "the set of bodies," "the temperature," "the quantity of heat per unit mass," and "the specific heat at constant volume" constitute a semantical model?

No. The set of entities; "the set of bodies," "the temperature," "the quantity of heat per unit mass," and "the specific heat at constant volume" does not constitute a semantical model.

Q and A 249: page 111; line 27; type IV, ii, C, c.

Is the set of statements; "the capital letters are sets or functions, 'R' is the real line, 'O' is the arithmetic product, etc;" a semantical model?

No. The set of statements; "the capital letters are sets or functions, 'R' is the real line, 'O' is the arithmetic product, etc;" is not a semantical model.

Q and A 250: page 94; line 30; type IV, iii, E-N, b.

The concept of one-dimensional models helping the attainment of understanding of three-dimensional phenomena is an instance of what generalization?

The concept of one-dimensional models helping the attainment of understanding of three-dimensional phenomena is an instance of the concept of crude models helping the attainment of understanding of complicated phenomena.

Q and A 251: page 93; line 25; type IV, iii, E-H, b.

What sort of thing was the solution that Ising obtained by grafting his model object onto general statistical mechanics?

The solution that Ising obtained by grafting his model object onto general statistical mechanics was a theoretical model.

Task V

Q and A 252: page 100; line 20; type V, i, A, c.

In what way is a theoretical model far richer than the bare model object?

Q and A 253: page 110; line 23; type V, i, A, c.

What is the difference between theoretical models and semantical models?

The difference between theoretical models and semantical models is that while theoretical models are sets of statements concerning some aspect of reality, semantical models are interpretations of abstract theories.

Q and A 254: page 110; line 24; type V, i, C, b.

In what ways are semantic models and metascientific models similar?

Semantic models and metascientific models are similar to the extent that they both contain designation rules and semantic assumptions that provide the abstract statements with factual content that can be assigned truth values.

Q and A 255: page 101; line 13; type V, i, C-H, b.

In what way is a grey box an improvement over the black box?

A grey box is an improvement over the black box in that the grey box specifies intermediate variables between the input and output rather than merely providing the latter as does the black box.

Task VI

Q and A 256: page 96; line 1; type VI, i, B, a.

What does it mean to say that a referent is not abstract?

To say that a referent is not abstract, is to say that it is a factual referent. This means that it (purportedly) represents some concrete (real) thing or event. It has empirical content.

Q and A 257: page 107; line 25; type VI, i, B-C, c.

What does it mean for a theory to be logically strong?

For a theory to be logically strong means that the theory has little empirical content. Thus, the truth or falsity of such a theory depends primarily upon the validity of its logical form rather than upon the state of things in the world.

Q and A 258: page 107; line 25; type VI, i, B-C, c.

What does it mean for a theory to be logically weak?

For a theory to be logically weak means that the theory has considerable empirical content. Thus, its truth or falsity depends upon the state of things in the world rather than upon the validity of its logical form.

Q and A 259: page 111; line 25; type VI, i, B-E, c.

What is meant by saying that the system of signs, A1 through A5, is nonsignificant?

By saying that the system of signs, A1 through A5, is nonsignificant, it is meant that the system is uninterpreted, which is to say that its terms, relations, operators, etc. have not been assigned meanings.

Q and A 260: page 92; line 23; type VI, i, B-H, b.

What does it mean to say that the real population, made up of different individuals, is modeled as a homogeneous (equivalence) class?

To say that the real population, made up of different individuals, is modeled as a homogeneous (equivalence) class means that all of the properties of the different individuals making up the set are ignored except for a selected property or properties so that the the set may be regarded as homogeneous in that the individuals all embody the selected property or properties without regard for any differences that they may display with respect to other properties.

Q and A 261: page 109; line 32; type VI, i, B-J, b.

What does "The same holds, *a fortiori*, for the diagram" mean?

"The same holds, *a fortiori*, for the diagram" means that the diagram, in some respects, a prototypical case of metaphor, can be expected to display its properties *par excellence*. In this case, the property in question is that of being misleading when used as the characterization of a model object.

Q and A 262: page 95; line 18; type VI, i, B-L, b.

What does it mean to say that a model object constitutes a profile of its referent?

To say that a model object constitutes a profile of its referent is to say that the model object displays one, or at most a few, salient aspects of its referent, but that it ignores many more.

Q and A 263: page 112; line 6; type VI, i, B-L, c.

What does it mean to say that the interpreted system, F1 through F4. is "a ready-made dummy?"

To say that the interpreted system, F1 through F4, is "a ready-made dummy" is to say that it could be fitted to any number of factual, that is empirical, interpretations.

<u>Q and A 264</u>: page 108; line 35; type VI, i, D, b.

How can the relation between hypothetical mechanisms and model objects be stated in terms of subsets and supersets?

The relation between hypothetical mechanisms and model objects can be stated in terms of subsets and supersets by saying that the set of hypothetical mechanisms forms a subset of the set of model objects, which is equivalent to saying that the set of model objects forms a superset of the set of hypothetical mechanisms.

<u>Q and A 265</u>: page 92; line 26; type VI, i, E, b.

What is the presentation of a collision of *m* cars having as a result *n* injured persons with a total damage of *p* dollars as an example of a referent and the ordered triple (*m*, *n*, *p*) as an example of a model object meant to show?

The presentation of a collision of *m* cars having as a result *n* injured persons with a total damage of *p* dollars as an example of a referent and the ordered triple (*m*, *n*, *p*) as an example of a model object is meant to show how model objects miss traits of their referents, discard details, omit inessentials, represent only certain significant aspects of the referent, model populations as homogeneous sets, and partition them into equivalence classes.

<u>Q and A 266</u>: page 98; line 15; type VI, i, E-L, b.

What does it mean to say that the McCulloch and Pitts model of the brain is a grey box model?

To say that the McCulloch and Pitts model of the brain is a grey box (semi-phenomenological) model means that it attempts to provide mechanism enough to account for only part of the results (input and output) that it represents.

<u>Q and A 267</u>: page 101; line 7; type VI, i, H, b.

What does it mean to say that the natural course is not necessarily the historical one?

To say that the natural course is not necessarily the historical one is to imply that one does not always start with the simplest model object and then proceed to complicate it bit by bit. Sometimes one starts with a complicated model object.

<u>Q and A 268</u>: page 101; line 12; type VI, i, H, b.

What does it mean to say that the hypothesized mechanisms must be conjectured?

To say that the hypothesized mechanisms must be conjectured means that must first the end result of the referent (what it actually accomplishes) must be considered, and then a mechanism that could plausibly account for that end result must be found.

Q and A 269: page 104; line 34; type VI, i, H-M, b.

What does it mean to say that inferring behavior from mechanism is a direct problem while conjecturing mechanism from behavior is an inverse problem?

To say that inferring behavior from mechanism is a direct problem while conjecturing mechanism from behavior is an inverse problem means that inferring behavior from mechanism is a problem in deduction while conjecturing mechanism from behavior is a problem in induction.

Q and A 270: page 101; line 15; type VI, i, H-Q-O, b.

What does it mean to say that the game is not just to account for appearance at any price?

To say that the game is not just to account for appearance at any price means that the attempt should be made not only to produce a mechanism that will adequately explain the end results of the referent, but come up with the actual mechanism that produces those results. This can be accomplished by showing some intermediate results that can be checked against those derived from the hypothetical mechanism.

Q and A 271: page 107; line 14; type VI, i, H-S, c.

What does it mean to pose a theoretical problem?

To pose a particular theoretical problem is to require an explanation for a set of observed facts about specific phenomena. More specifically, it is to represent those facts in a relatively succinct form.

Q and A 272: page 107; line 14; type VI, i, H-S, c.

What does it mean to solve a particular theoretical problem?

To solve a particular theoretical problem is to provide an explanation for a set of observed facts about specific phenomena. More specifically, it is to represent the explanation in a relatively succinct form, to wit: first, a model object; ultimately, a theoretical model.

Q and A 273: page 93; line 1; type VI, i, J, b.

What is meant by "idealizing reality?"

By "idealizing reality" is meant simplifying it, leaving out certain aspects of it.

Q and A 274: page 113; line 14; type VI, i, J, c.

What two meanings of "model" show up most prominently in theoretical science?

The two meanings of "model" that show up most prominently in theoretical science are those of "model object" and "theoretical model" (also called "specific

Q and A 275: page 93; line 3; type VI, ii, H-O, b.

Is the Rashevsky citation meant to inform the reader about how to go about performing a scientific investigation, or what?

The Rashevsky citation is not meant to inform the reader about how to go about the performance of a scientific investigation, but to describe some of the essentials of scientific investigation as necessarily performed by practicing scientists.

At this point, the presentation of the questions and answers associated with task-types III, IV, V, and VI which involve the tasks of description, classification, comparison, and interpretation has been made. In the next chapter, the presentation of the complete question and answer set will be concluded with the questions and answers associated with task-types VII and VIII involving the tasks of explanation and evaluation.

CHAPTER VIII

TASKS VII, VIII:
EXPLAINING, EVALUATING

In the previous chapters, the questions and answers numbered 1 through 275 have been presented. These questions and answers are associated with task-types I through VI. They involve the tasks of identification, specification, description, classification, comparison, and interpretation. In this chapter, the presentation of the complete question and answer set will be concluded. The questions and answers to be shown in this chapter, numbered from 276 through 345, are associated with task-types VII and VIII. They involve the tasks of explanation and evaluation (judging). These questions and answers follow immediately.

Task VII

Q and A 276: page 91; line 21; type VII, i, B, b.

In what way are model objects of themselves "barren?"

Model objects of themselves are barren in that they are untestable and, therefore, of no use to science.

Q and A 277: page 98; line 19; type VII, i, B-E, b.

Why did the McCulloch and Pitts model of the brain ignore the time of conduction along the axon and the variance of the synaptic delay?

The McCulloch and Pitts model of the brain ignores the time of conduction along the axon and the variance of the synaptic delay in order to avoid complicating the calculations with matters that were not central to what was being investigated.

Q and A 278: page 92; line 14; type VII, i, B-G, b.

Why do model objects capture only approximately the relations among the aspects they incorporate?

Model objects capture only approximately the relations among the aspects that they incorporate because referents worth modeling are too complicated to represent completely. The possession of sufficient knowledge of the referent to enable the construction of a model object capable of capturing the exact and complete relations among the elements that it incorporated would render the construction of such a model object unnecessary.

Q and A 279: page 104; line 16; type VII, i, B-H, b.

Why is the task of throwing light into boxes, for the theoretician, a task of invention rather than discovery?

The task of throwing light into boxes, is for the theoretician, a task of invention rather than discovery because the internal structures and mechanisms that are looked for are not visible for the most part. This means that they must be conjectured.

Q and A 280: page 107; line 25; type VII, i, B-H-N, c.

Why might the logical strength of a theory be expected to turn out to be inversely related to its ability to solve particular theoretical problems and to empirical testability of that theory.

The logical strength of a theory might be expected to turn out to be inversely related to its ability to solve particular theoretical problems and to the empirical testability of that theory because logical strength is gained only at the expense of empirical content, whereas particular theoretical problems are essentially about empirical content.

Q and A 281: page 98; line 12; type VII, i, B-L, c.

What is the reason for saying that simplicity is the privilege of either total ignorance or extreme generality (no detail)?

The reason for saying that simplicity is the privilege of either total ignorance or extreme generality is to justify the complication of theoretical models.

Q and A 282: page 92; line 13; type VII, i, C, b.

Why are model objects apt to include imaginary elements?

Model objects are apt to include imaginary elements as stand-ins for real elements whose nature is unknown but whose functions are known

Q and A 283: page 104; line 18; type VII, i, C-H, b.

Given that the functioning of a black box may explained by infinitely many hypotheses concerning the underlying mechanisms, what is to prevent the task of conversion from black box to built-up model from degenerating into a process of merely making an arbitrary choice from among them?

Although the functioning of a black box may be explained by infinitely many hypotheses concerning the underlying mechanisms, it is the requirement that the explanation fit into patterns of pre-existing knowledge that prevents the task of conversion from black box to built-up model from degenerating into a process of merely making an arbitrary choice from among them.

Q and A 284: page 100; line 25; type VII, i, C-H, c.

Why is it possible for the testing of theoretical models to "become as involved as one wishes?"

It is possible for the testing of theoretical models to "become as involved as one wishes" because, while a finite number of tests (even one, sometimes) can refute a theoretical model, only an infinity of tests could verify it completely. This means that theoretical models are verified only partially, to the point at which confidence is felt that the model is "True." And whether or not this point has been reached is a matter of judgement, so the testing "can become as involved as one wishes."

<u>Q and A 285</u>: page 102; line 19; type VII, i, C-H, c.

If a referent displays modes of behavior not in conformity with a definite law, how does this affect the construction of the theoretical model?

If a referent displays modes of behavior not in conformity with a definite law, the theoretical model must represent these different modes of behavior by means of appropriate laws, however definite or indefinite they may turn out to be.

<u>Q and A 286</u>: page 93; line 11; type VII, i, C-P, b.

Why is it necessary for Ising's model of matter in condensed states to assume that the units are ordered linearly?

It is necessary for Ising's model of matter in condensed states to assume that the units are ordered linearly because Ising's model is a one-dimensional model, therefore, the elements can be arranged only along a linear dimension.

<u>Q and A 287</u>: page 105; line 30; type VII, i, C-P, b.

Why must the referents of models be assumed to be real if the results are to have scientific value?

The referents of models must be assumed to be real if the results are to have scientific value because one of the basic premises of science holds that science proposes to deal with real things.

Q and A 288: page 101; line 30; type VII, i, C-Q, b.

In what way are grey boxes deficient?

Grey boxes are deficient in that their intermediate variables do not explain or account for the mechanisms of the referent; they only supplement them computationally.

Q and A 289: page 103; line 5; type VII, i, C-Q, b.

Why should the fact that black and grey boxes merely permit the attainment of computational results rather than also providing explanations of these results be considered a defect of these models?

The fact that black and grey boxes merely permit the attainment of computational results rather than also providing explanations of these results is considered a defect of these models because computational results generally remain isolated bits of knowledge rather than fitting with and adding to the great mosaic of human knowledge in general.

Q and A 290: page 108; line 12; type VII, i, D-E, d.

How are a rotating ellipsoid or a mass point related to the theories of gravitation and of light?

A rotating ellipsoid or a mass point are related to the theories of gravitation and of light in the following way. A rotating ellipsoid or a mass point are examples of model objects that can be associated with the general theories of gravitation and of light in order to produce theoretical models of the sun with its optical and gravitational manifestations.

Q and A 291: page 108; line 12; type VII, i, D-E, b.

How are the sun (along with its optical and gravitational manifestations) and a rotating ellipsoid or a mass point related to each other?

The sun (along with its optical and gravitational manifestations) and a rotating ellipsoid or a mass point are related to each other in the following way. The sun (along with its optical and gravitational manifestations) is an example of a referent for which a rotating ellipsoid or a mass point is an example of a model object. And, conversely, a rotating ellipsoid or a mass point is an example of a model for which the sun (along with its optical and gravitational manifestations) is an example of a referent.

Q and A 292: page 96; line 6; type VII, i, D-H-S, b.

Why should the modeling relation occur explicitly in any formulation of a scientific theory that takes care of the factual meaning of its symbols?

The reason that the modeling relation should occur explicitly in any formulation of a scientific theory that takes care of the factual meaning of its symbols is to avoid any possible confusion between the model (theoretical) and the modeled (referent).

Q and A 293: page 96; line 13; type VII, i, D-L, c.

Why is every formula containing the symbol of the modeling relation either an interpretative axiom or a semantic assumption?

Every formula containing the symbol of the modeling relation is either an interpretative axiom or a semantic assumption because such a formula relates the theoretical model s of a cell to the referent, or real cell r.

Q and A 294: page 95; line 29; type VII, i, E-F, c.

How is it possible to tell that S is the model object and M is the theoretical model, and not vice-versa?

It is possible to tell that S is the model object and that M is the theoretical model and not vice-versa by noting that S merely represents the referents themselves, while L, in addition to including R, also includes the mathematical representation of the properties of the referents as well as the relations between them.

Q and A 295: page 98; line 31; type VII, i, E-F, c.

How is it possible to know that stochastic models of the central nervous system constitute examples of theoretical models?

It is possible to know that stochastic models of the central nervous system constitute theoretical models because the mathematical apparatus that they must possess in order to be stochastic models provides assurance that they will also turn out to be theoretical models.

Q and A 296: page 106; line 6; type VII, i, E-G-H-O, b.

Why were the carbon atom and the hamiltonian operators mentioned?

The carbon atom and the hamiltonian operators were mentioned in order to exemplify the process of model construction in fields of research which have tended to produce unifying concepts rather than merely isolated bits of knowledge.

Q and A 297: page 106; line 5; type VII, i, E-H-O, d.

Why is quantum mechanics mentioned?

Quantum mechanics is mentioned in order to exemplify the process of constructing theoretical models in a field of research which has tended to produce unifying concepts rather than merely isolated bits of knowledge.

Q and A 298: page 111; line 1; type VII, i, F, c.

Why is it impossible for metascientific theories ever to qualify as semantic models?

It is impossible for metascientific theories (or, strictly speaking, their systems of factual interpretation, i.e., their model objects) ever to qualify as semantic models because those interpretations would have to make the theories come out true under all logically possible circumstances. This would, of course, be impossible since an infinite number of tests would be necessary to establish this. And this would, obviously, be impossible in the empirical world.

Q and A 299: page 111; line 7; type VII, i, F, c.

Why is it that some semantical models fail to qualify as metascientific models?

Some semantical models fail to qualify as metascientific models because, as purely formal systems, they lack empirical content.

Q and A 300: page 111; line 17; type VII, i, F, c.

Why does the system of signs, A1 through A5, not qualify as a semantical model?

The system of signs, A1 through A5, does not qualify as a semantical model because it is not an interpretation of a theory that makes the theory true in all cases, or even an interpreted theory whose interpretation makes it come out true in all cases (in the latter instance, it might loosely be termed a model by extension.)

Q and A 301: page 112; line 26; type VII, i, F, c.

Why does the set of entities; "the set of bodies," "the temperature," "the quantity of heat per unit mass," and "the specific heat at constant volume;" not constitute a semantical model?

The set of entities; "the set of bodies," "the temperature," "the quantity of heat per unit mass," and "the specific heat at constant volume;" does not constitute a semantical model because; while it does constitute a factual interpretation of the mathematical system, F1 through F4, and, hence, of the purely formal system, A1 through A5; precisely because it is a factual interpretation, it does not make these systems come out true in every case.

<u>Q and A 302</u>: page 111; line 27; type VII, i, F-L, c.

Why does the set of statements; "the capital letters are sets or functions, 'R' is the real line, 'O' is the arithmetic product, etc.;" fail to qualify as a semantical model?

The set of statements; "the capital letters are sets or functions, 'R' is the real line, 'O' is the arithmetic product, etc.;" fails to qualify as a semantical model because, while it is an interpretation of the system of signs , A1 through A5, it does not make the system true in all cases.

<u>Q and A 303</u>: page 95; line 21; type VII, i, G-H, b.

What good does it do to pretend that the domain of individuals to be represented can be partitioned into homogeneous subsets if they really cannot?

While the domain of individuals to be represented cannot be partitioned into subsets that are homogeneous in every respect, it really can be partitioned into subsets that are homogenous in one respect. But this is enough--if only one property is being controlled for.

Q and A 304: page 104; line 14; type VII, i, G-H, b.

Does the black box model have any use in the process of scientific inquiry?

Yes. The black box model does have a use in the process of scientific inquiry. But this use occurs primarily during the early stages of scientific investigation.

Q and A 305;: page 103; line 9; type VII, i, G-N, b.

Why might it be expected that the assumption that every system has an inner structure and mechanism will encourage research?

It might be expected that the assumption that every system has an inner structure and mechanism will encourage research because the assumption that a thing of value and interest exists can be expected to lead to attempts to discover what that thing is.

Q and A 306: page 92; line 15; type VII, i, H, b.

Why will most individual variations in a class be deliberately ignored and most of the details of the events involving those individuals be discarded?

Most individual variations in a a class will be deliberately ignored and most of the details of the events involving those individuals will be discarded because the function of a model object is usually the isolation and investigation of certain relevant properties of the referent classes. In general, science concerns itself with individuals only to the extent that knowledge of them leads to knowledge of classes.

Q and A 307: page 92; line 20; type VII, i, H, b.

Why may all the individuals of a given mice strain be taken to be indiscernible?

All the individuals of a given mice strain may be taken to be indiscernible because the model object is being constructed only to model the behavior of the mice with respect to their propensity to push bars for food pellets.

Q and A 308: page 92; line 21; type VII, i, H, b.

Why may all ways of pressing a bar for food pellets be assumed to be equivalent?

All ways of pressing a bar for food pellets may be assumed to be equivalent because only the propensity to push a bar for food pellets is being investigated by means of the model object, not the manner of pressing it. Any unnecessary complications introduced into the structure of the model object would be gratuitous. They would augment the amount of difficulty and work involved in the construction and use of the model object without any compensatory increase in the value of the results.

Q and A 309: page 93; line 29; type VII, i, H, b.

If complicating the model brings it closer to reality, why not make it more complicated right from the beginning as a way of saving time and effort?

Models are not always made as complicated as they eventually become right from the beginning because the knowledge gained from the construction of the early simpler models is often needed for the construction of later, more complicated, models.

Q and A 310: page 96; line 22; type VII, i, H, b.

Why is an explicit statement of the semantic assumptions mandatory in the axiomatic reconstruction of a scientific theory?

An explicit statement of the semantic assumption is mandatory in the axiomatic reconstruction of a scientific theory because the same mathematical formulas will sometimes fit more than one referent. For example, the flow of water in a pipe can be represented by the same (or analogous) formulas as the flow of electricity in a wire. Thus, an explicit statement of the semantic assumption is needed to make sure that there is no confusion regarding which formula is being linked to which referent.

Q and A 311: page 101; line 7; type VII, i, H, b.

Why is the method of starting with the simplest model object and then gradually proceeding to complicate it described as the natural course?

The method of starting with the simlplest model object and then gradually proceeding to complicate it is described as the natural course because the assumption is made that it is natural to proceed from the simple to the complicated. The assumption that this procedure is natural is probably derived from the observation that it frequently turns out to be convenient.

Q and A 312: page 104; line 16; type VII, i, H, b.

Why is the task of throwing light into boxes, for the theoretician, a task of invention rather than discovery?

The task of throwing light into boxes, is for the theoretician, a task of invention rather than discovery because the internal structures and mechanisms that are looked for are not visible for the most part. This means that they must be conjectured.

Q and A 313: page 106; line 29; type VII, i, H, c.

Why is it that theoretical models are obtained in the developing sciences by constructing a hypothetico--deductive system around the model object instead of attaching the model object to a general theory as is frequently done in the more advanced sciences?

Theoretical models are obtained in the developing sciences by constructing a hypothetico-deductive system around the model object instead of attaching the model object to a general theory as is frequently done in the more advanced sciences because, in the developing sciences, general theories are not as likely to be available as they are in the more advanced sciences.

Q and A 314: page 107; line 14; type VII, i, H, c.

What does it mean to pose a particular theoretical problem?

To pose a particular theoretical problem is to require an explanation for a set of observed facts about specific phenomena. More specifically, it is to represent those facts in a relatively succinct form.

Q and A 315: page 107; line 14; type VII, i, H, c.

What does it mean to solve a particular theoretical problem?

To solve a particular theoretical problem is to provide an explanation for a set of observed facts about specific phenomena. More specifically, it is to represent the explanation in a relatively succinct form, to wit: first, a model object; ultimately, a theoretical model.

Q and A 316: page 106; line 29; type VII, i, H-M, c.

Why is it that theoretical models are obtained in the developing sciences by constructing a hypothetico-deductive system around the model object instead of attaching the model object to a general theory as is frequently done in the more advanced sciences?

Theoretical models are obtained in the developing sciences by constructing a hypothetico-deductive system around the model object instead of attaching the model object to a general theory as is frequently done in the more advanced sciences because, in the developing sciences, general theories are not as likely to be available as they are in the more advanced sciences.

Q and A 317: page 96; line 18; type VII, i, H-M-S, c.

What error does the "semantical freak" involve?

The "semantical freak" involves a confusion between theoretical model and referent. The theoretical model is discussed as though it were the referent.

Q and A 318: page 95; line 10; type VII, i, H-Q, b.

How might the failure of the precise solutions obtained through the use of a simple model prove more instructive than the success of the vague solutions obtained by means of more complicated, hence realistic, models?

The failure of the precise solutions obtained through the use of a simple model might prove more instructive than the success of the vague solutions obtained by means of more complicated, hence realistic, models by indicating the kinds of modifications to the model that will produce more realistic models.

Q and A 319: page 95; line 21; type VII, i, H-Q, b.

What good does it do to pretend that the domain of individuals to be represented can be partitioned into homogeneous subsets if they really cannot?

While the domain of individuals to be represented cannot be partitioned into subsets that are homogeneous in every respect, it really can be partitioned into subsets that are homogenous in one respect. But this is enough--if only one property is being controlled for at a time.

Q and A 320: page 101; line 7; type VII, i, H-Q, b.

Why is the method of starting with the simplest model object and then gradually proceeding to complicate it described as the natural course?

The method of starting with the simlplest model object and then gradually proceeding to complicate it is described as the natural course because the assumption is made that it is natural to proceed from the simple to the complicated. The assumption that this procedure is natural is probably derived from the observation that it frequently turns out to be convenient.

Q and A 321: page 96; line 22; type VII, i, H-R, c.

Why is an explicit statement of the semantic assumptions mandatory in the axiomatic reconstruction of a scientific theory?

An explicit statement of the semantic assumption is mandatory in the axiomatic reconstruction of a scientific theory because the same mathematical formulas will sometimes fit more than one referent. For example, the flow of water in a pipe can be represented by the same (or analogous) formulas as the flow of electricity in a wire. Thus, an explicit statement of the semantic assumption is needed to make sure that there is no confusion regarding which formula is being linked to which referent.

Q and A 322: page 91; line 19; type VII, i, H-T, b.

Why would it not be preferable to construct a model object that could represent its referent in every aspect instead of in merely certain significant aspects?

It would not be preferable to construct a model object that could represent its referent in every aspect instead of in merely certain significant aspects because the possession of sufficient knowledge to construct such a model object would render its construction redundant.

Q and A 323: page 108; line 1; type VII, i, J, c.

What are "theoretical ideas?"

Theoretical ideas are, in effect, theoretical models or general theories.

Q and A 324: page 101; line 37; type VII, i, K-Q, b.

Why is the description of the model as a set of ordered pairs too coarse and uneconomical?

The description of the model as a set of ordered pairs is too coarse and uneconomical because every single input along with its corresponding output must be displayed. Thus, the description will tend to turn out lengthy and cumbersome.

Q and A 325: page 96; line 26; type VII, i, M-S, b.

Why is it important not to confuse the model object with its referent?

It is important not to confuse the model object with its referent because the same referent may be modeled by different model objects in different ways. Confusing the model object with its referent would, by obliterating or at least minimizing these differences, defeat the purpose of model objects--to discover ever "truer" ways of representing reality.

Q and A 326: page 95; line 29; type VII, i, N, c.

How is it possible to tell that S is the model object and M is the theoretical model, and not *vice-versa*?

It is possible to tell that S is the model object and that M is the theoretical model and not *vice-versa* by noting that S merely represents the referents themselves, while L, in addition to including R, also includes the mathematical representation of the properties of the referents as well as the relations between them.

Q and A 327: page 91; line 19; type VII, i, Q, d.

Why are general theories not sufficient for science?

General theories are not sufficient for science because they cannot be tested. Testing is, of course, necessary to science.

Q and A 328: page 104; line 14; type VII, ii, C-G-H, b.

Does the black box model have any use in the process of scientific inquiry?

Yes. The black box model does have a use in the process of scientific inquiry. But this use occurs primarily during the early stages of scientific investigation.

Q and A 329: page 92; line 12; type VII, iii, B-G-H, b.

Why do model objects always miss certain traits of their referents?

Model objects always miss certain traits of their referents because any referent worth modeling would be too complicated to represent completely. The possession of knowledge of the nature of the referent sufficiently ample to enable the construction of a model object that included every trait of its referent would render the construction of such a model object superfluous.

<u>Q and A 330</u>: page 108; line 25; type VII, iii, B-H, c.

Why is it possible for the testing of theoretical models to "become as involved as one wishes?"

It is possible for the testing of theoretical models to "become as involved as one wishes" because, while a finite number of tests (even one, sometimes) can refute a theoretical model, only an infinity of tests could verify it completely. This means that theoretical models are verified only partially, to the point at which confidence is felt that the model is "True." And whether or not this point has been reached is a matter of judgement, so the testing "can become as involved as one wishes."

<u>Q and A 331</u>: page 107; line 25; type VII, iii, B-H-N, c.

Why should the logical strength of a theory be expected to turn out to be inversely related to its ability to solve particular theoretical problems and to empirical testability of that theory.

The logical strength of a theory might be expected to turn out to be inversely related to its ability to solve particular theoretical problems and to the empirical testability of that theory because logical strength is gained only at the expense of empirical content, whereas particular theoretical problems are essentially about empirical content.

<u>Q and A 332</u>: page 98; line 12; type VII, iii, B-L-R, c.

What is the reason for saying that simplicity is the privilege of either total ignorance or extreme generality (no detail)?

The reason for saying that simplicity is the privilege of either total ignorance or extreme generality is to justify the complication of theoretical models.

Q and A 333: page 101; line 3; type VII, iii, C-D, b.

Why does the fact that there are many kinds of model objects imply that there are many kinds of theoretical models?

The fact that there are many kinds of model objects implies that there are many kinds of theoretical models because theoretical models inherit the characteristics of the model objects that they are based upon.

Q and A 334: page 104; line 18; type VII, iii, C-H, b.

If the functioning of a black box may be explained by infinitely many hypotheses concerning the underlying mechanisms, what is to prevent the task of conversion from black box to built-up model from degenerating into a process of merely making an arbitrary choice from among them?

Although the functioning of a black box may be explained by infinitely many hypotheses concerning the underlying mechanisms, it is the requirement that the explanation fit into patterns of pre-existing knowledge that prevents the task of conversion from black box to built-up model from degenerating into a process of merely making an arbitrary choice from among them.

Q and A 335: page 103; line 11; type VII, iii, C-N, b.

Why might the black box paradigm be expected to encourage superficiality?

The black box paradigm might be expected to encourage superficiality because the fact that this paradigm, by implication, ignores the possibility of the existence of an internal structure and mechanism of its referent. Thus, the paradigm discourages the attempt to discover the internal structure and mechanism whose existence it ignores.

Q and A 336: page 93; line 8; type VII, iii, C-Q, b.

Why should the one-dimensional representation of a tridimensional system be considered the most audacious of all model objects?

The one-dimensional representation of a tridimensional system should be considered the most audacious of all model objects because, although model objects inherently fall short of fully representing their referents, the one-dimensional model object's attempt to represent tridimensional referents can be considered particularly daring by virtue of the double handicap that it imposes upon itself by dispensing with two of the three dimensions that would ordinarily seem indispensable to the adequate representation of tridimensional referents.

Q and A 337: page 94; line 23; type VII, iii, E-F, c.

How can it be known that a linear model of a gas is a theoretical model?

It can be known that a linear model of a gas is a theoretical model because it has been stated that a linear model of a gas can mimic the condensation process. In order to mimic the condensation process, the model must specify the mathematical dimensions of the changes or movement that takes place. And if a model can specify the mathematical dimensions of the changes or movement that takes place, it must be a theoretical model.

Q and A 338: page 106; line 6; type VII, iii, E-G-H, b.

Why were the carbon atom and the hamiltonian operators mentioned?

The carbon atom and the hamiltonian operators were mentioned in order to exemplify the process of model construction in fields of research which have tended to produce unifying concepts rather than merely isolated bits of knowledge.

Q and A 339: page 91; line 18; type VII, iii, G, c.

Why are theoretical models necessary to science?

Theoretical models are necessary to science because they alone are testable. The unstated premise of this argument is that testing is necessary to science.

Q and A 340: page 92; line 11; type VII, iii, G-K, b.

Why is the representation of a concrete object always partial and more or less conventional?

The representation of a concrete object is always partial and more or less conventional because concrete objects are, as far as is known, inherently too complicated to fully represent. Also, the possession of knowledge of the referent of a model object as faithfully complicated as its referent would obviate the reason for constructing any model object of that referent.

Q and A 341: page 103; line 9; type VII, iii, G-N, b.

Why might it be expected that the assumption that every system has an inner structure and mechanism will encourage research?

It might be expected that the assumption that every system has an inner structure and mechanism will encourage research because the assumption that a thing of value and interest exists can be expected to lead to attempts to discover what that thing is.

Task VIII

Q and A 342: page 110; line 24; type VIII, i, S, b.

In section 10, it is stated that (1) semantical models are interpretations of formal systems that make all statements of the system true, (2) theoretical models (since their content is empirical) are never more than partially true so they cannot be semantical models, (3) the three empirical model objects described on page 112 are not always true, nonetheless (4) they constitute (or produce) semantical models. How is this possible?

This is not possible, it constitutes an unexplained contradiction. If semantical models are interpretations of formal systems that make all statements of the system true (1), and theoretical, hence empirical, models are never more than partially true (2), then it is manifestly impossible for them to constitute semantical models.

Q and A 343: page 100; line 17; type VIII, ii, A, c.

Are theoretical models necessarily true?

No. Theoretical models are not necessarily true; they may be either true or false.

Q and A 344: page 100; line 19; type VIII, ii, A-G, c.

Do some theoretical models manage to represent the full complexity of their referents completely and accurately?

No. No theoretical model ever manages to represent the full complexity of its referent completely and accurately. Any theoretical model of a concrete object is bound to fall short of representing the complexity of its referent.

Q and A 345: page 104; line 14; type VIII, ii, C-E-H, b.

Does the black box model have any use in the process of scientific inquiry?

Yes. The black box model does have a use in the process of scientific inquiry. But this use occurs primarily during the early stages of scientific investigation.

This concludes the presentation of the question and answers, numbered from 276 through 345, associated with task-types VII and VIII in this chapter and those of the complete question and answer set, numbered from 1 through 345, associated with task-types I through VIII in this this chapter together with the two previous chapters. The questions and answers displayed in this chapter involve the tasks of explanation and evaluation, while those presented in the three chapters terminating in this chapter involve the tasks of identification, specification, description, classification, comparison, interpretation, explanation, and evaluation. All that remains to be done now is to offer a brief summary of what has been accomplished or at least attempted in the present work. The conclusion, doing just that, will follow in the next and last chapter.

CHAPTER IX

CONCLUSION

In the preceding chapters, the problem of constructing an autodidactic tool for the study of a document in the philosophy of science has been formulated. The methodology involved in this undertaking has been discussed, and the results shown. It has been seen that this problem is translatable into the problem of using the document as a starting point for the generation of a set of questions and suggested answers that would in some way reflect the document's logical structure. Moreover, it has become apparent that this translation of the original problem can itself be resolved into a set of subordinate problems: (1) an analysis of the text to determine its conceptual elements, (2) an analysis of the methods of setting forth those conceptual elements within the text, (3) the formulation of a set of tasks that, when expressed as questions and answers, will promote, exercise, and test the student's conceptual grasp of the text, (4) the conversion of these tasks into such a question and answer set and (5) the categorization of the resultant questions and answers in a way that reflect the logical structures of the various conceptual elements, tasks, etc. that went into their formulation. Then a more or less detailed description of these analyses, determinations and formulations followed. The nucleus of the present work is the exhibition of the results of these procedures: the questions and answers themselves.

It is this nucleus then that, through its capacity both to mirror the conceptual content and to elucidate the concept structure of the objectdocument, can hopefully serve both as the basis of an auto-didactic approach to the understanding of this document and as a point of departure for the future application of this approach to study of other professional documents.

REFERENCES

Arons, Arnold B., Concepts of Physics. Reading, Massachusetts: Addison-Wesley, 1965.

Bloom, Benjamin S., ed. Taxonomy of Educational Objectives. New York: David McKay Company, Inc., 1956.

Mario Bunge, Method, Model and Matter, Chapter 5, "Concepts of Model" (Boston: D. Reidel Pub. Co., 1969) pp. 91-113.

Green, Thomas E., The Activities of Teaching. New York: McGraw-Hill. 1971.

Ennis, Robert H., Logic in Teaching. Englewood Cliffs, N. J.: Prentice-Hall. 1969.

Resnick, Robert and Halliday, Physics for Students of Science and Engineering. New York: John Wiley & Sons, Inc., 1960.

Smith, B. Othanel and Milton O. Meux, eds. Study of the Logic of Teaching. Illinois: Bureau of Educational Research, College of Education, University of Illinois. Project No. 258(7257). United States Office of Education.

APPENDIX

APPENDIX

The appendix consists of the document referred to throughout the present work as "the object-document" or "the object-text." The page numbers found in the identity-lines of the questions and answers refer to the page numbers of the original document. Thus, these page numbers have been retained along with the pagination of this work. These page numbers can be found on odd numbered pages of the object-document a little below and slightly to the right of the page numbers on the upper right corners of the pages of this work. And they will be found on the upper left hand side of the even numbered pages. However, the un-numbered title pages (89-91) of the object-document are located on pages 191-193 of this work.

METHOD, MODEL AND MATTER

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CHAPTER 5

CONCEPTS OF MODEL*

The purpose of this chapter is to elucidate the two notions of model that occur in factual (natural or social) science. These concepts are those of model object, or schema, and theoretical model, or specific theory. A clarification of these notions is needed in view of the ambiguity of the term 'model' and of the merry confusion, prevailing in the current scientific and philosophic literature, among various senses of this word.

We shall be concerned with model objects and theoretical models as hypothetical sketches of supposedly real, though possibly fictitious, things or facts. Thus a fluid may be modeled as a continuum endowed with certain properties, such as compressibility and viscosity. Such a *model object* may be grafted onto any of a number of general theories, say classical mechanics, or general relativistic mechanics. Likewise, a learning organism may be modeled as a black box equipped with certain input and output terminals, and this model object may then be expanded into a hypothetico-deductive system. In either case a specific theory, or *theoretical model*, of a concrete (or supposedly concrete) object, results. What can be subjected to empirical tests are such theoretical models: on the other hand general theories, being unconcerned with particulars, remain empirically untestable unless enriched with models of their referents. And model objects remain barren unless introduced in, or expanded into, some theory.

Besides offering elucidations of the concepts of model object and theoretical model, we shall examine their relations to several other concepts with which they are often mixed up. These are, in particular, the aesthetic sense (pictorial representation), the heuristic sense (analog of a familiar object), and the model-theoretic sense (realization or true interpretation of a formal system). It will be shown that any relation to these other characters is accidental and that model objects and theoretical models are not important by what they may suggest but by what they perform, to wit, a partial representation of a chunk of reality.

1. Concrete object and model object

A schematic representation of an object may be called a *model object*. If the represented object (or referent) is concrete or physical, then its model is an idealization of it. The representation may be pictorial, as in the case of a drawing, or conceptual, as in the case of a mathematical formula. It may be figurative, like the ball-and-spoke model of a molecule, or semisymbolic, as in the case of the contour map of the same molecule; or finally symbolic like the hamiltonian operator for that same object. The model object may be extratheoretical like the Pseudo Areopagite's model of the celestial hierarchy; or intratheoretical as in the case of the random net model of the brain.

The representation of a concrete object is always partial and more or less conventional. The model object will miss certain traits of its referent, it is apt to include imaginary elements, and will recapture only approximately the relations among the aspects it does incorporate. In particular, most individual variations in a class will be deliberately ignored and most of the details of the events involving those individuals will likewise be discarded. As an eminent economist says, "Typically they [models] are representations in which details, that appear inessential for intended uses, are omitted. A model is intended to represent the real thing in certain significant aspects" (Orcutt, 1967, p. 69). For example, all the individuals of a given mice strain may be taken to be indiscernible and all ways of pressing a bar for food pellets may be assumed to be equivalent as well. In other words, the real population, made up of different individuals, is modeled as a homogeneous set (an equivalence class), and likewise the set of all possible events is partitioned into homogeneous (equivalence) classes. For example, a collision of m cars having as a result n injured persons with a total damage of p dollars can be represented by the ordered triple $\langle m, n, p \rangle$. From the point of view of the traffic engineer all the car collisions characterized by the same triple of numbers m, n, and p are equivalent, even though the particular circumstances of interest to the victims, the doctors, or the police, may be quite different. The engineer may then assume that every fact f of this nature is represented by such a triple or, as we shall put it, that $\langle m, n, p \rangle \triangleq f$, where '$\triangleq$' designates the relation of model object to its referent. More on $\triangleq$ in Sec. 3 and Ch. 6. Let us now examine a striking kind of model, rather unrealistic and yet quite fertile.

2. Example: linear models of tridimensional things

The conceptual conquest of reality starts, paradoxically enough, by idealizing it. Whether in astronomy or in biology, in chemistry or in history, if we want to build conceptual models "we must begin with a study of non-realistic abstract situations. We cannot attempt to grasp any situation in its entire complexity. We must first study the partial, simpler aspects of a complex situation and then, as the next step, investigate the various possible combinations of those partial aspects" (Rashevsky, 1968, p. 16). Consider the most audacious of all model objects, namely, the one dimensional representation of a tridimensional system. The best known model of this kind is Ising's model of matter in condensed states. One assumes that the units (molecules or ions) are ordered linearly and each of them interacts but with its nearest neighbor. This oversimplified model of liquids and solids was proposed in 1920 by W. Lenz, who gave his student E. Ising the task of building the corresponding theoretical model. In other words, the problem was to construct the (or rather *a*) theory describing that model object of matter in a condensed state. (For the fascinating story of this theoretical model see Brush, 1967.) Ising did not have to start from scratch but was able to use an existing general framework, namely classical statistical mechanics. This is an extremely general theory that does not commit itself as to the nature of the individuals constituting a statistical ensemble and may therefore be "applied to" (conjoined with) a number of model objects. One such model object could be Ising's, another could be a sketch of an animal population. Ising grafted the model object onto statistical mechanics and worked out the exact solution (1925). But this solution failed to represent the typical qualitative transitions such as the jump to the ferromagnetic state. Diagnostic: The theoretical model is false. Since the generic framework (statistical mechanics) was judged to be basically correct, clearly the model object was responsible for the shortcomings of the theoretical model. Prognostic: If we complicate the model we may bring it closer to reality. But the task of solving the two dimensional Ising problem was too formidable: Ising got discouraged and gave up physics. The job was taken up two decades later by L. Onsager. His results were so good that we are justified in expecting even better results from the attempts to solve the tridimensional Ising problem, which is still open at the time of writing.

Surely this model, which among other things neglects the long-range interactions among molecules, is a simplified representation of matter. Still, it poses formidable mathematical problems – essentially the exact computation of the partition function, which yields all the macroproperties of the material system. Why invest so much ingenuity and labor in a model that is known to be physically too simple and mathematically too complicated? For no better reason than we would not know how to proceed otherwise than by successive refinements or complications of an initial coarse model. Whether the number of dimensions of a space is increased or decreased, whether the given is simplified or is assumed to be made up of suprasensible components, conceptual models are built and these are the only reasonable symbolic pictures of reality. Only models built with the help of intuition and mathematics, and susceptible to empirical tests, have succeeded in representing reality and can be corrected as need be. Moreover even a coarse model, like Ising's one-dimensional representation, is capable of explaining complex facts of interest to biology, such as the elasticity of macromolecules and the uncoiling of proteins (see Vol'kenshtein, 1970). A crude mathematical model is worth a thousand jeremiads on the defeating complexity of life.

Take a look at a recent volume devoted to some oversimplified models of physical systems: *Mathematical Physics in One Dimension*, by Lieb and Mattis (1966). One finds here classics such as the papers by Kac, Uhlenbeck, and Hemmer on a linear model of a gas capable of mimicking the condensation process; Dyson's article on the dynamics of a chaotic chain; the memoirs of Kronig and Penney on the movement of electrons in linear lattices, and many other imaginative contributions. They are not just exercises in applied mathematics but (crude) theoretical models of real objects: they propose full-fledged (but specific) theories specifying schematic representations of physical systems. Thus Dyson's random chain is a coarse model of the glass structure. All these fantasies intend to grasp reality. How? Listen to the editor-authors of this singular volume: The solution to one dimensional problems "make a contribution to the three-dimensional [account of] reality as well: by educating us to the need for rigorous and exact analysis, they lead us away from the easy and simplistic first theories toward a more critical and mathematical approach, and finally to a better definition [representation] of reality" (Lieb and Mattis, 1966, p. vi).

Surely a number of real complexities are discarded when working on model objects, whether one-dimensional, three-dimensional or pluridimensional. For example, a one-dimensional model of matter in a condensed state fails to represent condensation, freezing, and magnetization. But as a compensation one may obtain exact solutions, which are easier to interpret than the approximate solutions to more complex problems (in particular the numerical solutions obtained with the help of computers). What better preparation for facing more realistic, i.e., more complex, problems? Certainly one must expect that any such oversimplified model will fail. But the failure of a precise idea is more instructive than the success of a muddled idea, for it may suggest the precise modifications producing more realistic (truer) models. (For lucid discussions concerning the adjustment of theoretical models in contemporary psychology see Bush and Mosteller, 1955; and Sternberg, 1963.) Briefly, to grasp reality one starts by sifting the available information and discarding most of it. Then one adds imaginary (or rather hypothetical) components – though with a realistic intention. One thus constitutes a more or less schematic model object. This model object is hoped to constitute a profile of its referent.

3. The Modeling Relation

As we recalled in Section 1, one starts modeling by pretending that the domain(s) R of individuals to be represented can be partitioned into homogeneous subsets S, i.e., into subsets all of whose elements are identical in a given respect. We then attribute each member s of every such equivalence class S certain key predicates $P_1, P_2, \ldots, P_{n-1}$. These predicates stand for properties and relations (in particular functions) that are for the most part unobservable. (Although these predicates are defined on S, they will be satisfied only approximately, if at all, by the ultimate referents, i.e. the members of R.) We thus form a relational system $M = \langle S, P_1, P_2, \ldots, P_{n-1} \rangle$ intended as a conceptual model of the concrete referents R. In short, M models R or, briefly, $M \triangleq R$.

The model object, if theoretical, is a more or less elaborate construct: a set together with a few functions, a ring of operators in a Hilbert space, or what have you. It need not and in general it is not intuitable: but it always has a factual referent, even if hypothetical. For example, social mobility in a community can be represented by a certain transition probability matrix. Such a matrix is not a picturable model object but it is not altogether abstract either, for it represents jumps of real people from one social rung to another: it is a factual construct or, better, a construct with a factual referent. In other words, the relation $\triangleq$ of modeling is included (in extension) in the set of all ordered pairs $\langle c, f \rangle$, where c is a construct and f a fact.

The modeling relation $\triangleq$ should occur explicitly in any formulation of a scientific theory that takes care of the factual (physical, psychological, historical, etc.) meaning of its symbols (Bunge, 1967b). Thus in theoretical biophysics one may assume that a cell r is represented by, or modeled as, a subset s of a differentiable manifold on which certain real valued functions are given, that represent so many properties of the cell (temperature, density, etc.). We may then write '$s \triangleq r$' and similarly for the predicates. Every formula containing the symbol '$\triangleq$' of the modeling relation may be called an *interpretative axiom* or a *semantic assumption*. If written out *in extenso*, any theoretical statement in factual science will contain the modeling relation. Thus the formula for the total mass of a cell r will be: "If $s \triangleq r$, then $M(r) =_{df}$ the Lebesgue integral of the mass density over the set s". If no such precaution is taken, a semantical freak such as 'the total mass of the set s' is apt to be engendered.

In informal scientific discourse one rarely takes pains to state explicitly any such semantic assumptions: they are usually hinted at in what undergraduates call "the conceptual part of the stuff." But an explicit statement of the semantic assumptions is mandatory in the foundations of the science and in particular in the axiomatic reconstruction of a scientific theory, if only because any given mathematical formalism fits a number of kinds of concrete object: it is noncommittal and thus ambiguous. An explicit exhibition of the modeling relation will not only indicate what one is talking about but may also constitute a reminder that the object model, though hoped to represent a certain thing, is not the same as it. It is never useless to insist that every model object is an idealization of a system or a fact taken to be real or realizable. There are as many idealizations as idealizers, data, and goals. Even if two model builders have access to the same empirical information, they may construct different models, for model building is a creative activity engaging the background, abilities, and taste of the builder. Hence the worries of administrators and politicians, about the "unnecessary duplication" of theoretical work, are unfounded. Instead, the absence of communication among the model builders faced with the same problem (but likely to come up with different results) does justify an ulcer or two. So does the playing around with model objects without ever expanding them into full-fledged theoretical models.

4. From model object to theoretical model

It is not enough to conceive of a liquid as a molecular lattice or of a brain as a neuron net: all this has to be described in detail and, if possible, in agreement with the known general laws. In other words, one must build a theory of the model object, i.e., a theoretical model. The kinetic gas theory is such a theoretical model, whereas neither general statistical mechanics nor thermodynamics are theoretical models of a gas, since they do not specify the peculiarities of a gas *vis-à-vis* other kinds of system. Nor is general graph theory a theoretical model: on the other hand some of its applications, e.g., to human organizations such as enterprises, are theoretical models. From these examples we infer a first characterization of the notion of a theoretical model, namely this. A *theoretical model* is a hypothetico-deductive system concerning a model object, which is in turn a schematic conceptual representation of a thing or of a situation assumed to be actual or possible. If such a specific theory is couched in exact (mathematical) terms, it is often called a *mathematical model* of a certain domain of facts (see, e.g., Neyman *et al.*, 1959). Let us review a distinguished specimen of this kind of animal.

The current theory of the solid state was founded by Bloch four decades ago. Bloch's master idea was to apply wave mechanics (a generic theory) to a simple model of the crystal. The constituents of this model object are a set of fixed points representing an atom each, and a bunch of electrons (or rather model electrons) wandering among the fixed centers. The lattice of fixed centers (fiction) is assumed to be rigid (fiction), the interaction among the electrons is set equal to zero (fiction), and the electron-lattice interaction is represented by a potential that is periodic in space but constant in time (approximation). This model object is next conjoined with the vast framework of quantum mechanics. In the course of the computations some additional mathematical simplifications may have to be introduced. However, the results are frequently in agreement with the experimental data, which suggest that a nearly true image of a real crystal (a nonpictorial image to be sure) has been built. Thus, although initially one does not postulate any difference among conductors, semiconductors, and insulators, this partition is obtained upon analyzing the distribution of energy levels (or rather bands). These bands are separated by "forbidden" regions (no states). If every band is occupied by the electrons, then there will be no electric current, i.e. the system will be an insulator. This theoretical model explains numerous macroproperties of most pure crystals: their thermal and electric conductivities, magnetic susceptibility, optical properties, etc. Some other properties, such as luminiscence, are explained upon complicating the Bloch model by adding impurities, assuming disorder in the lattice, and so on. The more traits a theoretical model is to take in and the more accurately it is to represent them, the more complex it will have to be. Simplicity is the privilege of either total ignorance or extreme generality (no specific detail at all).

The procedure is the same in the nonphysical sciences. Consider the brain model proposed by McCulloch and Pitts three decades ago. This model covers only the nerve fibres and it does not account for the mechanism of the nerve pulse: it is a semiphenomenological model (or grey box theory) that will have to be supplemented with models accounting for the physical and chemical process of nerve conduction. Also the time of conduction along the axon is ignored, and the synaptic delay is assumed to be constant and the same for all neurons. Next one formulates the central hypothesis of the theoretical model: that a neuron does not fire unless the preceding neurons have fired during the preceding moment (i.e., no spontaneous firings and no effect before the cause). This statement is translated into mathematical formulas, one for each type of connection. Once in the possession of these formulas one attempts to embed them in an existing mathematical calculus: otherwise one will have to invent a new mathematical theory. In the present case, the ready-made mathematical foil was Boolean algebra. In this way McCulloch and Pitts succeeded in constructing a theory that explains some neurophysiological processes. If one wishes to go beyond he will have to complicate this model. For example, if synaptic contacts are assumed to be formed randomly, then one can pose and solve the question of the chance formation of certain nervous loops – which should in turn explain the appearance of ideas that seem to come out of the blue (i.e., without external stimulation). Which is precisely what Rapoport and his coworkers have done, namely to develop stochastic models of the central nervous system.

Stochastic models became fashionable in mathematical psychology when it was realized that animal behavior is far from consistent and systematic. There are thus numerous stochastic models of the process of learning simple tasks such as running a maze under reward or punishment. All these models share the following traits. Firstly, they ignore differences among animal species as well as the differences in the tasks to be learned. Secondly, they discard all the biological variables: they focus on stimuli, responses, and the effects of the latter (in particular reward and punishment), thus bypassing the central nervous system. Thirdly, in each model the central hypothesis is a formula for the probability of response of a subject as a function of the number of trials. This function varies from one model to the other. In any case, what is usually called a 'stochastic learning model' is actually the central hypothesis of a specific theory (= theoretical model) in consonance with the general framework of learning theory. (The hypothesis in question is central by virtue of being accompanied by subsidiary hypothesis concerning either the mathematical structure of the constructs involved or their factual content.)

In sum, once a model of the thing has been conceived, the model has got to be characterized in exact terms with the help of mathematical concepts, such as those of function and series. If possible, the resulting specific theory should be inserted into a comprehensive theoretical schema. This, a common practice in the physical sciences, is hardly possible in the new sciences, rich though they are in grandiose but woolly conceptions. Backward disciplines include at most such conceptions, developing areas have only theoretical models, and advanced fields include both theoretical models and vast theories that make room for theoretical models. (Recall Chapter 2.)

5. Theoretical Models

Not all model objects are conceptual and those which are may not be theoretical models although they can constitute bases for such specific theories. A necklace of multicolored beads can represent a chain polymer, and a sociogram may represent some of the relations among the individuals in a community, but the former is a physical model or analogue while the latter is just a data display. Even the Watson-Crick model of DNA is a model object which, at the time of writing, is still in search of a full theoretical description, or expansion into a theoretical model. In order to obtain a theoretical model, the model object must be either blown up or embedded into a theoretical framework. Upon being absorbed by a theory, whether existing or created *ad hoc*, the model object inherits the peculiarities of the theory and, in particular, whatever law statements the theory may contain. Thus a model cell, if adjoined to the general theory of diffusion, will satisfy the latter's diffusion equation: otherwise it will not be able to mirror an intracellular diffusion process.

Let $M=\langle S, P_1, P_2, \ldots, P_{n-1}\rangle$ be a model of a concrete object of the kind R, i.e. let $M \hat{=} R$. Further, assume that the various coordinates of M are logically independent from one another, i.e., not interdefinable. Then any consistent set of conditions (postulates) specifying the structure (mathematical nature) of the n primitive concepts, as well as their factual meaning, will be a *theoretical model* of R. In other words, a theoretical model of a collection R of things is a hypothetico-deductive system with primitive base M. (The axiomatizability condition is sufficient but not necessary for getting a theoretical model, but it is necessary in order to give a quick and exact definition of the concept.) Whether any given theoretical model is true to some extent is another matter.

Any theoretical model of a concrete object is bound to fall short of the complexity of its referent, but in any case it is far richer than the bare model object, which is just a list of traits of the concrete object. Thus if a planet is modeled as a mass point, or even as a ball, not much is said. It is only by further assuming that such a model satisfies certain law statements, in particular laws of motion, that we get a piece of scientific knowledge. Look at a few more examples:

Thing or fact (referent)	Model object (conceptual schema)	Theoretical model (specific theory)
Deuteron	Proton-neutron potential well	Quantum mechanics of the p-n potential well
Solute in dilute solution	Perfect gas	Kinetic theory of gases
Traffic at rush hour	Continuous flow	Mathematical theory of traffic flow
Learning organism	Markovian black box	Bush and Mosteller's linear operator model
Bunch of singing cicadas	Collection of coupled oscillators	Statistical mechanics of an ensemble of coupled oscillators
Enterprise	Flow chart	Inventory theory

6. From the Black Box to the Mechanism

There are many kinds of model object and, consequently, of theoretical model. At one end of the spectrum we find the black box equipped only with input and output terminals. At the other end we find the box filled up with mechanisms, more or less hidden, serving to explain the external behavior of the box. The natural course (but not necessarily the historical one) is to start with the simplest model object, one without a structure. One then proceeds to assign a simple structure, e.g., by dividing the original box into two, and he may continue this process of successive complications till whatever was to be explained gets in fact explained. Since the hypothesized mechanisms are not usually on display, they must be conjectured. This conjecturing may or may not be based on existing knowledge: for example, the mechanism may be assumed to consist in a known field or in a newly invented one. In either case the game is not just to account for appearance (observable behavior) at any price, but to try to guess the actual mechanism. In other words, it is not a question of imitating Ptolemy's epicycles or even the "virtual" particles and processes of contemporary physics, which discharge only computation duties but have no real referents (Bunge, 1971d). Hypothetical mechanisms should be taken seriously, as representing the innards of the thing. To take such conjectures seriously is to demand that they be empirically testable: an occult mechanism that fails to show up in any distinctive way, that stays aloof from the known portion of the net of laws, and that is contrived only to comply with the data, is no more than a makeshift.

Consider any system whatever, machine or animal, molecule or institution, and assume we wish to describe and predict its behavior without for the moment being concerned with either the composition of the processes that may occur inside the system. In this case one will build a black box model that will constitute a representation of the global functioning of the system – just like the idea a young child has of a TV set. Assume further that all environmental factors but one are disregarded, and call I the strength of that factor, or input. Assume also that the system has a single property that is influenced by the input: call O the intensity of the output, or response of the system to the environmental stimuli I. The simplest representation of the events involving the box will be a table displaying the various couples $\langle I, O\rangle$ of the values of the input and the corresponding output. Each event will then be represented by one such ordered couple, which will be a model event. But this description of the model is too coarse and uneconomical. We shall gain by replacing the table of observed values by a hypothesized general formula relating the set of input values to the set of output values (or some function of it). Such a formula will represent, in a concise and general fashion, the behavior of the model system without saying a word about the events going on inside the system. If the formula is related to other formulas, and particularly if one succeeds in inserting it into a general theory, one will get a black box model of the system. Such a simplistic representation may temporarily assuage our cognitive thirst, particularly if our ultimate goal is to use the system rather than to know all about it or to improve on it.

The next stage in the theoretical investigation of the system will consist in introducing further variables of the same types (inputs and outputs). A time may come when one or more variables of a third type will have to be introduced, namely variables S specifying the internal state of the system. The law of the system, or rather a schematic representation of one of its laws, will then be a formula tying up the three sets of variables, I, O, and S, or rather a whole bunch of formulas involving these variables. If the system cannot only react in a certain manner, i.e., in conformity with a definite law, but can also jump into some other form of behavior, be it spontaneously or under the influence of an external stimulus, then the theoretical model will have to be enriched with the laws of such a behavior change. (Think of a watch used as a projectile or of an individual taking an LSD dose.) In any case a theoretical model of the behavior of a system is a set of statements, preferably mathematical formulas, relating the exogenous variables I and O and the endogenous variables S of the system. Since no mechanism has been conjectured, the box is still dark; but since it has been assigned internal states, it is grey rather than black. In other words, the theoretical model includes endogenous variables but the latter do not represent any detail of the inner structure of the system: they are just intervening variables with a computational rather than representational value. (For a rich set of black and grey boxes, see Zadeh and Desoer, 1963. For a general black box framework, see Bunge, 1963b, and for a philosophical analysis see Bunge, 1964.)

A *behavior model* of a system will satisfy the requirements of empiricist philosophies (positivism, pragmatism, operationism, phenomenalism) as well as of conventionalism since, without going much beyond the data, it enables one to condense the latter and even to predict the evolution of the system. But no model of this kind, be it a black box or a grey one, will *explain* the behavior both external and internal of the system. Moreover it will remain isolated from the rest of our knowledge of things or at least it will make no use of it. To obtain such an explanation and to establish contacts with other theories and, *a fortiori*, with other disciplines, we shall have to try a *build-up model* of the same system, i.e. we must disclose the inner structure and the mechanism of it. (That every system has an inner structure and mechanism, is a rather bold metaphysical assumption that has always encouraged research, whereas the black box paradigm encourages superficiality.) Such a disclosure is not difficult to perform in the case of a clock, at least if we remain content with a macrodescription. But in general, whether we have to do with light or with chemical bonds, with thought or with institutions, the task is hard and probably open ended. The reason for this is that most of the structures and mechanisms responsible for appearance are hidden to the senses. Hence, instead of attempting to see them we must try to imagine them. Even if we finally succeed in observing a part of the inner structure and mechanism, we shall have made hypotheses and shall have checked them. For example, to explain the semiphenomenological law of multiple proportions we must posit molecules made up of atoms. Thus, by assuming that the water molecule is composed of two hydrogen atoms and one oxygen atom, we account for the macrofact that two volumes of hydrogen combine with exactly one volume of oxygen. (Incidentally, this hypothesis was rejected by the energetists of the turn of the century, who argued along positivist lines against the positing of any hidden structure and mechanism: thermodynamics, a grey box theory, was enough for them.)

To most drivers a car is a black box: they operate the levers and switches knowing what behavior they will induce thereby but they know little if anything about the engine and the transmission mechanism. Likewise most computer users know how to operate computers but have only faint ideas about their build-up. To a machine designer, on the other hand, a car and a computer are transparent or at least translucid boxes rather than black ones. (However, every single component of a machine may be handled, for practical purposes, as a black box. It behoves the physicist or the chemist, rather than the engineer, to find out what is inside the box.) It would be absurd to laugh at drivers and computer programmers for taking a phenomenological approach with respect to the machines they operate since, unlike the engineer, the user of a machine is is supposed to treat it as a means not as an end. But it would be equally absurd to criticize research engineers for not remaining satisfied with the external approach and for wishing to know what mechanism each switch controls. Yet that is precisely what the behaviorist (phenomenalist, positivist, black boxist) philosophy does: it derides all those who inquire into the *modus operandi* of things. In particular, black boxism discourages the attempt to unveil the neurophysiological mechanisms of the mind: it asserts not only that psychology can bypass the brain in a first stage of research, but that it must do so as a matter of principle. Enforcing black boxism in science would be like banning car designers and mechanics: after a while there would be no more cars to be driven. In sum, while the black box is a useful model, it should be only a preliminary one.

An aim of research is to throw further light into every box. As far as the theoretician is concerned this task is one of invention rather than discovery. There is considerable leeway in the transition from a black box to a translucid box. Indeed the functioning of a black box may be explained by infinitely many hypotheses concerning the underlying mechanisms. For every function f relating the inputs I to the outputs O there are infinitely many pairs of functions g and h such that g maps the set I of inputs into a set S of intermediaries (e.g., internal states) and h maps S into the set O of outputs, subject to the condition that the composition of g and h equals the given function f. If the intervening variables are interpreted in factual (e.g. biological) terms, then one gets infinitely many possible mechanisms for every black box – provided the various hypotheses are *not* required to be in tune with any known laws of nature.

Empiricists hold this ambiguity to be a shortcoming of any model that covers more than the observable external behavior. On the other hand realists regard that as a virtue of the translucid box approach for, if one is lucky enough to find (or rather invent) the real mechanism, then the apparent behavior remains uniquely determined by that mechanism, whereas the converse is false. In other words, if a mechanism is posited then one derives its behavior, whereas if the latter is given the former can only be guessed. (Inferring behavior from mechanism is a direct problem; conjecturing mechanism from behavior is an inverse problem, hence a much harder one.) Any such guess must of course be checked. The outcome of such a control may be regarded as successful, i.e. the mechanism hypothesis may be taken to be confirmed *pro tempore* if it satisfies the following conditions: (*a*) it accounts for the observed behavior; (*b*) it predicts new facts, not covered by the black box model, and some such predictions are borne out by new observations or experiments; and (*c*) it is consistent with the bulk of the known law statements. (For a list of criteria for the evaluation of scientific theories see Bunge, 1967a, Chapter 15.)

One may then propose a variety of models of any given system: the black box, the grey box with internal states, or the translucid box equipped with a mechanism. One may try causal boxes or stochastic boxes, i.e. boxes with random features built into them. One may build single level boxes (e.g., physical models) or multilevel boxes (e.g., psychosocial models). The choice among these various model objects and the corresponding theoretical models depends not only upon the nature of the system itself but also upon the goal of the investigator. If the aim is just to handle a system, then a black box may suffice. But if one wishes to understand how the system works, be it out of intellectual curiosity or with a view to improving on it, then he must imagine more complex models enjoying the support of general theories as well as of new experiments. As an eminent biologist wrote à propos of muscle models (Pringle, 1960), the postulation of a conceptual model is unnecessary if the goal is the synthesis of data: in this case the goodness of fit is the only requirement. But if the objective is further data analysis, or the construction of a compass for a deeper experimental exploration, then it will be necessary to imagine theoretical models, which alone will justify adopting a given "empirical curve" rather than any other curve fitting the same empirical data. In sum, it is up to us to decide which road to take: superficial knowledge (description and prediction of behavior) or deep knowledge (explanation and ability to explain unheard-of effects). But in either case we have to do with the construction of model objects and theoretical models of supposedly real things.

7. Generating theoretical models

In some fields of research the theoretical model is built around the model object. In others the model object can often be attached to an existing general theory. Thus in contemporary mathematical sociology there is hardly a generic theory: here every theory proper (as distinct from a vague view) is specific and the various specific theories do not seem to assemble into a single comprehensive theory. On the other hand in atomic and molecular physics the construction of theoretical models usually consists in applying a generic theory (frequently quantum mechanics) to models of the thing concerned. Thus, if we wish to generate theoretical models of the carbon atom, we try symbolic models of it (namely, hamiltonian operators that gather basic properties such as the number of electrons and their interactions) and plug such model objects into the general theory.

Any given model object can, within bounds, be conjoined with a number of general theories to yield as many different theoretical models (specific theories) of the real object concerned. Example: the model of a gas as a swarm of point particles connected by van der Waals forces may be inserted either in classical or in relativistic particle mechanics, to yield two different theoretical models of the gas. Conversely, a number of model objects can be associated to any given general theory provided they are couched in the language of the latter. Example: assume different particle shapes and different force laws but keep classical mechanics throughout: you will obtain different theoretical models of the gas. Whenever general theories are available, theoretical models can then be generated in either of two ways: either by embedding a given model object into different general theories, or by grafting different model objects onto a given generic framework. In either case a theoretical model is a generic theory together with a model object. More precisely, when a generic theory T_g is available, a theoretical model or specific theory T_s can be built by adjoining to T_g a set S of subsidiary hypotheses, i.e. $T_s = T_g \cup S$. These subsidiary hypotheses characterize ("define") a given model object.

This does not hold for the developing areas of science, where most of the time model construction proceeds centrifugally, out of model objects. Here one starts out from some M and tries to weave a net of formulas characterizing M in as precise a manner as possible. Consequently problem solving is hardest in the underdeveloped fields of research: here one must make a fresh start almost every time, relying only on data on the one hand and on pure mathematics on the other, without the guide of a comprehensive framework. Such a guide can often be taken for granted in the more advanced areas. For instance, nowadays the theoretical meteorologist starts from the general equations of hydrodynamics and thermodynamics, which are assumed to hold regardless of the atmospheric composition. His job is often to contrive a set of subsidiary assumptions representing the composition of the real atmosphere – i.e., to devise a model atmosphere. Atmosphere pollution by industry, as well as atmospheric clean-up, will force him to change the model object, hence the theoretical model of the atmosphere – not however the general equations. This enviable position is certainly not the one attained so far by psychologists and sociologists, who are still waiting for their second conceptual revolution – the first one having been the introduction of mathematical models.

8. Models and testability

Particular theoretical problems, that is, problems concerning the representation of specific situations, can be posed and solved only within specific theories of some scope or other. By the same token, only specific theories (theoretical models) are empirically testable: the general theories yield no particular conclusion, hence no precisely testable one. Thus, in the case of mechanics, if we wish to find, say, the modes of oscillation of a particular structure, such as a shell, we have to specify the external forces, the mass and stress distributions, the constitutive equations of the material, and the boundary and initial conditions – in short, we have to enrich the general theory with a definite model shell. In sum, model-free theories are not empirically testable.

A first conclusion: both the ability to solve particular theoretical problems and the empirical testability of a theory are inversely related to the logical strength of the theory. Second: the testing of general theories calls for the production of specific ones: by themselves, the extremely general theories, such as information theory, and even theories of intermediate breadth, such as quantum mechanics, are untestable, as was argued in Chapter 2. What can be tested is only a specific theory, i.e., a theoretical model, whether or not it is the outcome of attaching a model object to a generic theory. Third, in testing a theoretical model in an advanced field, where comprehensive theories are available, it is not always clear which is to be blamed in case of failure: whether the general theory, or the model object, or both – even assuming the data themselves to be blameless. Let us take a closer look at this situation.

If the theoretical model T_s disagrees with the facts and if one can be reasonably certain that this dissonance is not the fault of the empirical data, then the theoretical ideas will have to be revised. If T_s is not embedded in a comprehensive framework, then one has to try different central hypotheses, leading to as many alternative theoretical models. But if T_s is embedded in a generic theory, then we have a double infinity of possible alternatives. In fact, in this case one may either change the model object M characterized by T_s without touching the generic framework T_g, or one may keep M and adopt or construct a different general theory T_g. Thus, if certain calculations on the propagation of light in the vicinity of the sun do not agree with the data, then one may try either complicating the model of the sun (e.g., rotating ellipsoid instead of mass point), or changing the general theory of gravitation or that of light. The type of change one may find advisable will depend critically on the services rendered in the past by both the general theory and the model object. If the comprehensive framework has had a distinguished career or if the model object is obviously much too coarse, then it will be wise to keep the former and try an alternative model object. (If Dicke and Brans had taken this methodological rule into account they might not have proposed an alternative to Einstein's gravitation theory.) But if the general theory has failed in the past, or else if it is very young and cannot be assigned a truth value, then it will be advisable to try alternative theoretical systems with a wide scope. In any case, the verification procedure of such a generic theory cannot dispense with the construction of a number of model objects, and the test of any theoretical model can become as involved as one wishes (see Bunge, 1970). So complex indeed that no clear cut decision is attainable in some cases. For example, to date one does not know which of the various stochastic models of learning is the truest, even though they are quite different from one another (see Sternberg, 1963; Ritchie, 1965). All of which casts doubts on the simplistic methodologies of science advising us to adopt a theory if, and only if, it agrees with the evidence.

9. Models, mechanisms, analogs, pictures

Every hypothetical mechanism of a process is a model object but the converse is not true: not every conceptual model sketches a mechanism. Thus a black box is a model that ignores inner mechanisms. Moreover mechanism models need not be mechanical or mechanistic. Thus the mechanisms of electromagnetic propagation, of complex chemical reactions, and of biological evolution, are nonmechanical, i.e., they are modeled in ways that are foreign to mechanics. At any rate the frequent identification of model object with mechanism – an identification inherited from the mechanistic period of physics – is mistaken.

Nor need model objects be deterministic: they may be probabilistic. In other words, some or even all of the predicates occurring in a model object may be random variables. Thus every specific stochastic learning model is centered on some formula expressing the response probability at the *n*th trial as a function of the event(s) preceding that trial. Any such formula may be taken either at its face value or as representing a definite random process. In the latter case it will be said to embody a stochastic model, or a chance mechanism, of the process.

Also, while some models are literal and unfamiliar, others are analogical, i.e., conceived in imitation of familiar situations. Thus an unreliable person may be regarded as similar to a vending machine out of order, that delivers the goods only a fraction of the times it swallows a dime. This is an example of an analog or simulate: the real thing (the unreliable fellow) is modeled on a model of a known kind (a machine out of kilter), and the resulting model object can be embedded in a generic theory, namely the theory of Markovian machines. Conceptual analogs can of course be as respectable as material analogs or simulates, but the point is that they constitute a proper subset of the set of model objects. Many, perhaps most, model objects are literal and more or less uncanny (to the layman) rather than analogical and familiar. Thus there are no adequate analogical models of electrons, ecosystems, and markets. Furthermore, the insistence on analogical models, such as the particle and the wave analogies, is responsible for a great deal of confusion in the quantum theory (Bunge, 1967e). At any rate, the characterization of the model object as a metaphor, which has recently been revived (Black, 1962; Hesse, 1966), is misleading.

The same holds, *a fortiori*, for the diagram, which – except in pure mathematics – may be regarded as a kind of analog. In factual science a diagram is a visual and sketchy representation of a model object: it pictures the latter without replacing it. Being more or less conventional, a diagram is not a unique representation of its referent and is consequently unintelligible unless accompanied by some interpretation code. The various pictures of a model object need not be isomorphic to one another and consequently they cannot replace the object they picture even though they can help to understand it. For example, the alternative representations of the motion of a set of coupled oscillators, in usual coordinates and in "normal" (interaction-free) coordinates, are theoretically equivalent, whereas the corresponding symbolic diagrams are not: while in the former case the various dots are linked with springs, in the latter case they are unattached. At any rate, pictorial diagrams are not part and parcel of factual theoretical science although they may illustrate some parts of a theory in equivocal ways. They are not for the simple reason that a theory is, by definition, a set of statements not a mixture of statements and pictures. Pictures and, in general, metaphors, may occur in the process of building, learning, teaching or applying a theory but they are not part of the theory.

In summary, there are many kinds of model object: mechanical and nonmechanical, deterministic and stochastic, literal and analogical, figurative and symbolic – and so on. None of these properties is desirable in itself, for what makes a model object work is something else, namely its being an idea concerning some aspects of a thing or of a fact, and as such something that can be expanded into a hypothetico-deductive system.

10. Theoretical Models and Semantical Models

In semantics, and particularly in model theory (the semantics of pure mathematics), the term 'model' signifies an interpretation of an abstract theory, under which (interpretation) all the statements of the theory are satisfied (or true). For example, since the integers (Z) satisfy ring theory, the structure $\mathscr{Z} = \langle Z, +, \cdot, 0, 1\rangle$ is a model of ring theory, itself an abstract theory admitting alternative models. What is the relation between this semantic concept of model and the metascientific concepts of model object and theoretical model? Clearly every scientific theory, whether generic or specific, is an interpreted theory in the sense that, if properly formulated, it contains both designation rules and semantic assumptions endowing the formalism with a factual content. (Recall Chapter 4.) Moreover, if such an interpreted theory did turn out to be wholly true it would qualify as a model, in the semantic sense, of the underlying abstract formalism. But things are not quite so simple.

Firstly, not all theoretical models have been subjected to tests for truth: consequently they cannot all be assigned a truth value. Secondly, every tested theoretical model proves to be at best partially true in the sense that, with toil and luck, some of its testable statements turn out to be approximately true. Therefore no theoretical model is, strictly speaking, a model in the model-theoretic sense, for this requires the exact satisfaction of every formula in the theory. Nor is it true that all semantical models are models in the metascientific sense. Thus *ad hoc* models and mathematical models (interpretations within mathematics) mirror no real systems. Since the arrow points in neither direction, the semantic and the metascientific concepts of model do not coincide – *pace* Suppes (1961). What might be said is that a theoretical model that has been given a pass mark constitutes a *quasi*model of its underlying formalism. But this semantic concept of quasimodel has yet to be elucidated. In any event, the model-theoretic or semantic concept of a model fails to capture the metascientific concepts of model. A simple example will bear out this conclusion.

Consider the following system of signs

A1 $S \neq \varnothing$.

A2 (*a*) $F: S \to R$. (*b*) $G: S \times S \to R$. (*c*) $H: S \times S \to R$.

A3 $s, s' \in S \Rightarrow H(s, s') = h \in R$.

A4 (*a*) $\bigcirc: R \times R \to R$. (*b*) $\square: R \times R \to R$.

A5 $s, s' \in S \Rightarrow G(s, s') = h \bigcirc [F(s') \square F(s)]$

This system of signs is nonsignificant. We may assign it as many meanings as interpretation codes we care to adjoin it. Let us do it in two stages. In a first stage let us interpret the capital letters either as sets or as functions, according to the context. Moreover, we shall stipulate that 'R' stands for the real line, '$\bigcirc$' for the arithmetic product, and '$\square$' for subtraction; the remaining symbols shall be assigned the standard interpretation. In this way we obtain the following interpreted system

F1 S is a non-empty set.

F2 (*a*) F is a real valued function on S. (*b*) G and H are real valued functions on the set of pairs of members of S.

F3 H is the constant function with value h.

F4 For every s and s' in S, $G(s, s') = h[F(s') - F(s)]$.

This is a formalism interpreted within pure mathematics. It makes no sense outside mathematics. In particular, it is not a theoretical model in any metascientific sense of the term, for it does not concern anything extramathematical: the basic set S is an arbitrary (abstract) set and therefore the functions F, G, and H cannot represent any concrete properties. Precisely this renders the formalism valuable from a scientific point of view, for it is a ready-made dummy that can be clothed in a number of ways.

To transform the preceding formalism into a theoretical model of a concrete thing it is necessary and sufficient that the primitive concepts S, F, G, and H be interpreted in such a way that the resulting theory will in fact concern real (or supposedly real) objects. See here two, among many other, possible factual interpretations of the preceding formalism:

Symbol	Physical interpretation	Sociological interpretation
s	Point on a d.c. electric circuit	Country
$F(s)$	Electrical potential at s	Enticement offered by s (e.g., standard of living)
$G(s, s')$	Intensity of current between s and s'	Migratory pressure from s to s'
$H(s, s')$	Conductivity between s and s'	Permeability of the border between s and s'.

The very same formalism is of course susceptible to further alternative interpretations in factual terms. For example, if S is interpreted as the set of bodies, F as the temperature, G as the quantity of heat per unit mass, and H as the specific heat at constant volume, we get the nucleus of elementary thermology. If we interpret S as the academic body, F as the number of publications, G as professional jealousy, and H as natural hatred, we obtain a theoretical model of an important aspect of Academe. In sum, we have alternative semantical models of an abstract structure and each of them seems to be a theoretical model of some real system.

But this is just a first approximation. We know, in fact, that the first model is inadequate (false) at low temperatures. The second model does not seem to have been subjected to an empirical test, so that we can assign it no truth value. This situation is not exceptional but common. Indeed, all the theoretical models that have been checked prove to be more or less distant from full truth: they are not and they could not possibly be completely true, since they all involve simplifications. Consequently every theoretical model is, in the best of cases, a *quasi*model in the sense that its formulas are (at best) satisfied only approximately by reality. Therefore the model-theoretic concept of a model does not coincide with either of the two metascientific notions of model. Which shows that model theory is not enough to constitute the semantics of science, and suggests that the very term 'theoretical model' (and also 'mathematical model') would be advantageously replaced by 'specific theory'.

11. Conclusion

To sum up, the term 'model' designates a whole set of concepts that should be distinguished. In theoretical science, whether natural or social, the term seems to have been assigned two main significations: (*a*) that of schematic representation of a concrete object (i.e., model object), and (*b*) that of theory characterizing a model object. A theoretical model lives as long as experience tolerates it. On the other hand a general theory lives as long as it can generate reasonably true theoretical models. Being special purpose devices, theoretical models are transient and disposable as compared to general theories. The latter, being more adaptable, last longer. While the young sciences can boast, if at all, of their theoretical models, a mature and healthy science evolves theories of both kinds.

NOTE

* Based on Bunge (1968c, 1969c).

APPROVAL SHEET

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The final copies have been examined by the director of the thesis and the signature which appears below verifies the fact that any necessary changes have been incorporated and that the thesis is now given final approval by the Committe with reference to content and form.

The thesis is therefore accepted in partial fulfillment of the requirements for the degree of Master of Arts.

August 31, 1984
Date

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Director's Signature