CHAPTER 5

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A "description" details aspects of an event, e.g., the pigeon pecked the key 25 times; Johnny ran across the room. "Prediction" is the correct description of something which has not yet occurred, e.g., the pigeon will peck 25 times; Johnny will run across the room. "Cause," in its simplest common language usage, correctly specifies the efficient cause or the necessary and/or sufficient difference in the environment which immediately preceded the resulting change in behavior, e.g., when the spider fell on his arm, Johnny ran across the room. "Knowledge" is covariance in nature. This can be anything from a tone changing across time to the flip of a switch and the lights coming on to the change in the pattern of what we see as we look out a train window. It is a more general term than cause. "Explanation" is more than knowledge and more than the cause of something. Explanation is the specification of the context within which knowledge exists such as the ancillary factors necessary and/or sufficient for the cause-effect relationship, the origin of that behavior, and how that relationship will change with changes in the context.

II. What is an Explanation?

Explanations are one of the products of science and are a special case of the vicarious system illustrated in Chapter 4 Section I. B. 2. In Chapter 1 a preliminary lexical definition of explanation was provided. In this chapter, we more adequately characterize explanation.

A paradigmatic framework provides the context necessary for acceptable explanations. In fact, a paradigm can be said to come into existence when a group of investigators is interested in the same sort of phenomena and accept the same types of explanation. Adequate explanation within a paradigm is to a degree determined by the curiosity of the pioneers of that subsequently popular paradigm. Curiosity led those individuals to particular questions and the satisfaction of their curiosity determined their explanatory system. To the degree that their choices were revealed to be productive, then the paradigm prospers. To be degree that their choices were not astute, the paradigm declines and is replaced.

Explanation can be considered the activity which successfully pacifies curiosity because it allows an event to be predicted, controlled, and synthesized. That specification is integrated within a coherent paradigm so that events never before experienced can also be better understood. Additionally, explanations allow prediction, control, and synthesis in different contexts.

An explanation for an event brings to bear a wide variety of multiple converging evidence by pointing out how that particular process or relationship is only one of a great many similar ones which can be said to follow the same rules. Obviously however, what pacifies curiosity at one time may not be an adequate explanation in the light of new challenges. Following a discussion of the characteristics of an explanation, the types of explanations will be detailed.

A. Components of an Explanation

Explanations can address more or fewer factors pertaining to the occurrence of a relationship or class of relationships. In this sense, explanation can be more or less complete and more or less general.

1. Rules of the Paradigm

A full explanation must provide the rules of the paradigm from which the explanation flows. The meaning of a paradigm was discussed in Chapter 2. It is only within some paradigm that many issues can be resolved. For example, if one of the basic rules of the paradigm is "empiricism" and "determinism," then explanations for what happened to your money, such as "an invisible spirit stole it" or "it simply disappeared" are not acceptable explanations.

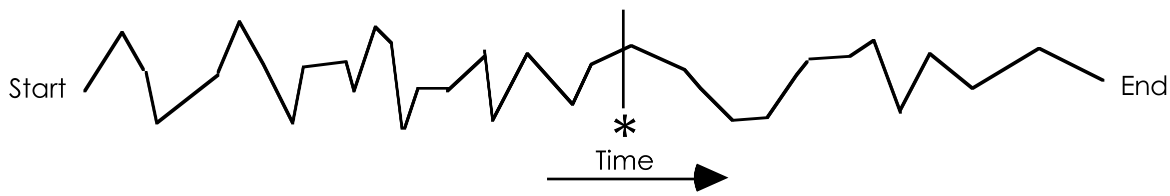
The paradigmatic context for the explanation may be more or less broad. For example, while empiricism may be applicable for all sciences, "behavior is a function of its reinforcement history" is applicable only to psychology.

2. Functional Properties of Relationships

Functional relationships include two types of variables: those which predict, control, or cause some measurable output; and those which are the result or effect, or predicted variable.

a. Controlling or Causal Variable

Understanding the functional properties of a relationship is an essential element of science and a fundamental purpose of an explanation. Understanding the nature of the functional properties of a relationship also allows us to better understand how Aristotle's four causes (material, efficient, formal, and final) relate to "explanation." His causes can be seen as various temporal segments of the functional properties of a relationship in time. The following figure illustrates the meaning of his terms.



Suppose that the asterisk indicates the moment in time that we turn on a green light which a pigeon immediately pecks. Suppose further that the erratic function to the left of the asterisk indicates how all the component elements of the relationship preceding the green light and the pigeon key peck changed as the result of environmental events back to the “big bang” (e.g., the bird’s evolution and the bird’s reinforcement history) and that the erratic function to the right of the asterisk indicates how the behavior and those same component elements change as the result of environmental events to the end of time (e.g., the bird evolves further and experiences additional reinforcement contingencies). To be more precise the two lines diverging from the light, and key peck event should be illustrated with infinitely complex and infinitely diverging tree like lines but in order to keep the illustration manageable, single lines are used. We now have a depiction of all historical and future cause-effect relationships relating to that green light and the subsequent key peck. We have the complete functional properties of that relationship in time. Note that the function extends across all time rather than for a few minutes or a few years. If time is bounded, then the function extends from the beginning of time to the end of time; if time is unbounded, then “start” and “end” have no meaning.

i. Material Cause

This is the entire segment of the function to the left of the key peck. It is the component parts from which something comes, such as the raw materials of a tree; earth, air, sunlight and water. In psychology, the material cause of a behavior is its prior history (including evolution) or its underlying physiology from which the functional relationship is built. This includes all historical events that contributed to the key peck occurring, i.e., those pertaining to the pigeon and the green light. These historical events can be productively broken down into various time scales. (These time scales are discussed more fully in Chapter 7 Section III. A. 3.)

(a) Instantaneous Time Frame or Efficient Cause

This is the segment of the function which immediately precedes the key peck The immediate propelling factor which sets an event into motion such as the woodsman's chopping causing the tree to fall. It is the onset of the green light. The green light could be said to cause the key peck just as the woodsman's chopping down a tree can be seen as the cause of the tree falling.

A simple behavioral example would be the onset of an eliciting stimulus such as meat powder in the mouth causing salivation.

(b) Short Time Frame Cause

This would be the local ontogenic history of the pigeon and all of its causal functions. The most notable would be the reinforcement history that resulted in the green light coming to control a key peck. Note that this too could be labeled the cause of the pecking.

(c) Medium Time Frame Cause

This would be the developmental history of the pigeon and all of those causal functions. An example would be those relationships which enabled the pigeon to grow and develop to the point that it could see and peck the green light. Again, the label “cause” could be invoked.

(d) Long Time Frame Cause

This is the evolutionary history of the pigeon back to a single cell organism and beyond, all the way back to the big bang. It includes all the causal functions which had as an end result, all the properties of our pigeon and the green light, such as the strong and weak forces. Obviously, the term cause is again applicable.

ii. Formal Cause

This is the specification of the "rules of nature." It is the specification of what differences in the environment produce what differences in nature. The formal cause is the process which resulted in all of the events prior to and following the asterisk. It specifies how the behavior of the pigeon and green light (and everything else) changes as a function of nature. As an end, it will result in the final cause.

iii. Final Cause

By definition, this is the right most endpoint of the function. It is the “goal” of the function. If time is seen as unbounded then this category has no meaning and final cause is equivalent to the formal cause of a thing.

A final cause view often mistakenly presumes that things get better and better over time. Rather, things change until they stop changing. A boulder is jostled and it rolls down the mountain into one valley or the other. It does not choose its goal. It is responding to the simple forces applied to it.

iv. Intervening Reductionistic Cause

This is the specification of the reductionistic events between changes in the environment and the behavior of the organism. Reductionism is more fully discussed in Chapter 6, and a conceptual scheme for the integration of various levels of reductionism is presented in Chapter 7. Explanations which emphasize reductionistic machinery are labeled mechanistic explanations. The term cause is also invoked for this relationship in statements such as “brain activity in the motor cortex caused the arm to move.”

(a) Biological Machinery

This is the specification of the cellular events which mediate between the environment and the behavior. For example, activity in the bird's retina then brain then muscles for a green light causing a key peck.

(b) Chemical Machinery

This is the specification of the chemical events which mediate between the input to a cell and the cell's output. This machinery is the basis of all cellular activity. For example, ATP is converted to ADP in the muscle cells producing a change in the shape of the muscle.

(c) Quantum Machinery

This is the specification of the quantum events which mediate between the input to an atom and its response to that event. This machinery is the basis of all atomic activity.

v. Population or Contextual Cause

An additional aspect of an explanation is the specification of how the relationship fits within the population. Most typically in Psychology this would be the percentage of animals that respond in a particular way to some stimulus conditions or training procedure. Again the term cause can be applied to this type of relationship. For example, if most children who grow up in a particular culture exhibit a particular trait it is often said to be caused by the culture.

vi. Conditional Causation

(a) Sufficient Cause

A sufficient cause is one which is capable of causing an event to occur but which is not essential to its occurrence. A match, candle, and spark are each sufficient to ignite gasoline but none are necessary. Light is sufficient to elicit pupillary contraction, but it is not necessary; for example, drugs and emotional state can also contract the pupil.

(b) Necessary Cause

A necessary cause is one which is essential for an event to occur. Oxygen is essential for gasoline to ignite and burn, however it is not sufficient. Life is necessary for pupillary contraction, but it is not sufficient.

b. Controlled, or Effected Variable

i. Onset/Offset

One type of effect is to cause an event to occur or terminate. For example, hitting oneself on the thumb causes one to change from being silent to yelling. The causal relationship between hammer blows and yelling can be easily demonstrated experimentally.

ii. Modulation

A modulating influence is a factor which can alter characteristics of a behavior but which does not necessarily turn the behavior on and off. While hitting oneself on the thumb with a hammer may be seen as the cause for screaming out; the words selected to articulate the exact nature of your feelings are modulated by the people near you. The causal relationship between the types of people and your vocabulary can also be demonstrated experimentally.

3. Conceptual Follow-Up: Causation

The preceding terms related to the notion of causation. Each captured some element of the concept, but as you can see, their specific usage is not without some problems. The inference of necessary and or sufficient causation implies some frame of reference. For example, if the frame of reference is allowed to change without limit then establishing the sufficiency of some element is problematic. In establishing light as sufficient to elicit pupillary contraction in an animal it is presumed that the range of conditions does not include living and dead animals. Aristotle's enumeration of causes revealed additional complexities of the term. While we tend to think of a single event like the woodsman's chop as the cause of a tree falling, we could alternatively point to the role of a cold winter (which generates a need for firewood) as the cause.

Besides enumerating conceptualizations of causation, this section makes it clear why the terms "cause" tends to be avoided in scientific discourse. Too many different things could be intended by the term. The speaker and listener may not have the same referent in mind. Note however that simply using some euphemism for the cause effect relationship such as the controlling controlled relationship; or the predictor predicted relationship (or whatever), diverts our attention from, more than avoiding, the problem. As with a great many issues, always presume a long list of fine print disclaimers and conditions accompanying the usage of "cause" such as: "from this conceptualization," and "other things being equal." The required specifications are usually left out but presumed in order to more clearly present the important issues without submerging those issues in an ocean of disclaimers.

4. Explanatory Anchor

a. Within Time and Unit Domain

These are explanations that specify input/output functions within the same time and unit domain, e.g., reinforcement history for pecking.

b. Across Time Domains

These are explanations for a behavior which appeals to a different time scale for explanation. Unit domain may or may not be confounded, e.g., the reproductive advantage provided by some specific behavioral equilibrium such as a response rate of 2 responses per second to some specific reinforcement rate.

c. Across Unit Domains

These are explanations for a behavior which appeal to a different unit domain for explanation. Time domain may or may not be confounded, e.g., the cellular processes underlying a particular behavior.

d. The Multidetermination of Behavior and Confounding

An organism's adaptation can occur at any or all of a variety of unit and time domains and any change in behavior is best seen as the result of the sum of all the changes across all of those processes. Alternatively stated this means that changes at any unit or time domain other than the one under consideration can confound the interpretation of the effect of interest, if not understood or held constant.

Those factors not explicitly of interest must be considered and treated as sources of potential confounds. Successful predictions which consider only a single unit of molarity or time scale are actually special cases and are subject to failure if variables from other "contexts" are changed.

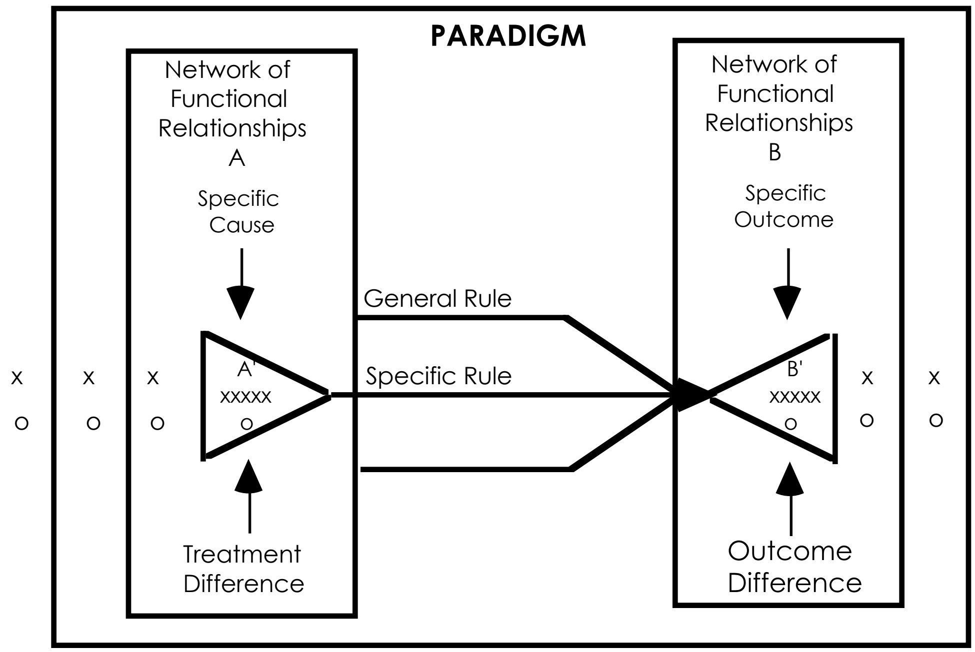
B. Characteristics of an Explanation

Explanations can be seen as very broad "if A then B" statements, where A is some well integrated general conditions or rules characterizing the functional properties of nature, and the detailed specification of the conditions under which the effect will occur, e.g., if you hold a match under a piece of paper, then the paper will catch fire, provided that the atmosphere ... the composition of the paper is ... and the temperature of the paper is elevated to ... It occurs because of the rapid ... It can be extinguished by ... or ...

Specifically, there is a difference between two sets of observations (B versus B') to be explained, e.g., most pieces of paper just lay there, this piece catches fire. This difference in observations is to be understood by relating it to the differences in treatments received by the two groups of paper (A versus A') and the integrated framework within which that result was the obvious necessity of the factors involved (paradigm). Explanations are generally presented as a result (B') and then its explanation (A') (e.g., the paper caught fire because a match was held under it and those conditions work in such and such a way). The explanation for why the pigeon pecked a green key is the specification of the context for the set of causes for that result such that those specifications "make sense" out of that result. It allows us to understand the event and not to be surprised by it. If we know all the treatments in advance, we could have predicted it.

A simple diagram may help depict the various requisites of an acceptable explanation. The various aspects are detailed in the sections below. Those characteristics could be seen as nothing more than the ramifications of the demand for good operational/functional definitions, or the logical consequences of the demand for "truth" and "understanding." The issues are reiterated in this section in terminology more typically applied to explanations.

The figure below represents the general paradigm with the outer box. This represents the set of rules within which everything is seen. These rules were discussed in Chapter 2. The left inner box represents the network of functional relationships that could be generally categorized as those related to the cause. These are both very broad such as the functional properties of reinforcement to more specific such as the reinforcement history of the particular pigeon to very specific such as a green light turning on. The right inner box represents the network of functional relationships pertaining to the output or result of the various causal factors. These are the various behaviors which could occur given variations in the causal factors. The inner triangles represent the specific cause and specific outcome. These are all the causal factors specifically relating to the situation of interest These would tend to spread out as they were further removed form the green light going on very much as parents, grandparents, and great grandparents diverge as they are further removed from the child. On the output side a similar effect occurs as the time since specific output increases there is growing divergence in the possible outcomes due to the action of additional causal factors.



1. Factual

The sets A, B, A' and B' and even the paradigm itself each include elements and exclude others. The elements (i.e., the Xs and Os) comprising those sets and the set boundaries must be empirical, reliable, consensually valid, operationally/functionally defined, and have multiple converging support.

a. Analogy Versus Explanation

Analogic explanations are advanced with little actual support, or simply by analogy. They are not necessarily true. The model may have only rhetorical or presumed similarity to the phenomenon to be explained and is, therefore, an unacceptable explanation. Recall at this point that acceptable explanations must be empirical, reliable, consensually valid, operationally defined, and have multiple converging support. Analogies do not have this type of broadly based necessary connection to nature. For example, "pressure builds up in the id until it breaks through and causes this behavior." This is a hydraulic metaphor with substantial support as an explanation of gas station grease racks but no support for being applicable to the behavior of people. When people say they are Freudian, more than likely what they actually believe is that a hydraulic system would work that way (e.g., if pressure builds up enough then something will burst, thus "relieving" the pressure). They are so caught up in the plausible validity of the physics of a hydraulic mechanism that they forget to ask if it applies to human behavior. The syntax is so compelling they ignore the semantics (Chapter 4 Section I. B. 2. b.). Similar analogies can be drawn from computer science or whatever discipline is currently experiencing "glamorous" findings. Freud developed his theoretical model of human behavior when hydraulics were the popular craze in engineering. It is likely that superconductivity or nonlinear dynamical analogies will be offered as an explanation of human behavior within a few years. It may very well be right - but it may also be wrong even though it is at the height of fashion.

b. Folklore Versus Explanation

Often, notions creep into "common knowledge" without passing any test to assure that they are true. A surprisingly common pathway is that offhand, unproven possibilities presented in discussion sections are repeatedly invoked as if they were the point proven in the procedure. Soon it becomes common knowledge that a particular paper proved something that it did not.

2. Explicit

An explanation must be explicit. The boundaries of A, B, A', B', and the paradigm must be clearly stated. Which elements are included and which are excluded must be unambiguously specified. In order to properly explain a phenomena the communication must explicitly and clearly specify the proposed mechanisms or rules (syntax). Statements must be unambiguously connected to the empirical world (semantics).

Ambiguous statements give only the illusion of successful explanation. In retrospect, they seem to have been right. However they actually say nothing because they could be construed to have contended anything. The oracle at Delphi once predicted to a king "if you attack Persia, a great kingdom will fall." The visitor attacked on the basis of the "favorable" prediction - and lost. Not realizing that the oracle would have been right either way. His own great kingdom fell. In sum, there must be a clear and unambiguous way to determine which elements are contained and which are not contained in the sets.

a. Set Definition

Sets may be defined in a number of ways. The value of any particular method of defining a set is governed by its productiveness with respect to the larger paradigm.

i. Elements

A set may be defined by enumerating each of its elements, e.g., this is a chair, this is a chair, this is not a chair.

ii. Rules

A set may be defined by a rule which determines which elements are included, e.g., chairs are surfaces suspended above the floor which … they are not …

(1) Functional Definition

A set of behaviors may be defined as all those behaviors which result in the same "end"; examples would be as diverse as "key peck," "go home," or "clean up." As with any other type of definition, only to the extent that these functionally defined sets enter into orderly relationships are they meaningful.

b. Specificity

i. Qualitative Explanation

This is a simple qualitative specification of the expected change in the dependent measure with the occurrence of some independent variable. For example, the explanation could predict that the response rate should increase with the occurrence of a reinforcer. However, there is no attempt to specify a quantitative change as a function of the independent variable.

ii. Quantitative Explanation or "Model"

Models specify a change in the dependent variable as a function of a change in the independent variable and also suggest an algorithm which publicly and reliably produces results similar to an actual subject. If the model does not specify outputs in terms of inputs it is of little real use. If it makes correct predictions, then the model explains by virtue of working. Ideally, the proposed mechanism process or function breaks the mathematical specifications of the functional relationship into easy to conceptualize factors which may have empirical reality. There are situations however where the specification may not lend itself to easy conceptualization in three dimensions. Physics gave up easy conceptualizations decades ago.

Various implementations of theories based on models may or may not suggest additional dimensions such as: that its proposed mechanism is inside the organism (reductionistic); that nature works toward that end (teleological); or it may simply provide the relationship between inputs and outputs without adding hypothetical or intervening elements (correlative).

There are therefore three aspects to models: 1) their specificity and power to predict specific empirical relationships (qualitative versus quantitative); 2) the proposed dimension at which the explanation functions (e.g., reductionistic), and 3) the presumed empirical reality of the proposed process. These three aspects are often confused.

Quantitative models of behavior are becoming the method of choice in the analysis of behavior. Any model which correctly predicts and correctly quantifies the relationship between the environment and behavior is potentially of great importance. Competing models are to be judged on the basis of their ability to produce all those elements presented under "truth" and "understanding" and further elaborated in Chapters 10 and 11. A model must have generality, must be accurate and must minimize free parameters. It must also have theoretical machinery which correctly links it to other levels of paradigmatic molarity and time scales of adaptation.

c. Nontautological

An explanation must not be tautological. The boundaries of A, B, A', and B' must be different. The A or A' cannot be a restatement of the B or B'. It is not acceptable to simply describe an event and then turn around and use that description as the cause for that event. For example, "the paper is burning because something caused it to catch fire." If you do that, you are not dealing with a functional relationship (an input and output, or a cause and effect). Rather you are simply talking about an effect and then using a synonym for that effect as the cause. Explanations for behaviors must add to our knowledge or understanding, not simply rearrange the words. If you were to consult a dictionary or an expert with the following question: "What does the principle of 'scientific manipulation' mean," and they responded: "that's when you manipulate things scientifically," then you would not be happy and you would not have gained much. Tautological explanations are similar: they explain why a phenomenon occurs by nothing more than a verbal smoke screen. When a functional relationship between two elements is proposed, both elements must be unambiguously and independently connected to separate empirical events.

3. Testable

An explanation must be testable. The boundaries of A, B, A' and B' must allow someone to clearly predict whether an element is within or not within the set before being told by the proponent of the explanation. The boundaries cannot be a secret!

a. Confirmable

At least one element must be predicted by the rules and obtainable as the result of empirical confirmation.

b. Falsifiable

A second "testability" criterion is known as falsifiability or making a risky prediction. A useful theory or therapy must tell you something that isn't obvious to everyone. It must contribute to your knowledge or ability to solve problems or it has no value. If I tell you that a coin toss will result in a “head or a tail” then I haven't told you anything that you didn't already know even though future events will prove my prediction "true." If a theory predicts that a person will either get better, get worse, or stay the same then it hasn't said anything that any fool doesn't already know even though future events will prove that prediction "true." If a theory says that a person will not get worse but will either stay the same or get better then it has narrowed down the possibilities and has told you something useful. In doing so however, it has put itself at risk, in that, the person could actually get worse and prove the theory wrong. It can be seen therefore, that in order to say anything, a theory must take a stand and put itself at risk. A simple way to tell whether or not a theory would be useful therefore is to determine if it makes any risky predictions. Can it be falsified? Not all results can lead to confirming the theory.

The information transmitted (or the degree of understanding conveyed) in a communication is the amount of uncertainty reduced. Note the following figure. If you had to guess the value of a number between 1 and 10, and I told you that it was the number 6 (see line B), then I would have reduced your uncertainty to zero

<- - - - Range of Problem - - - ->

A	1	2	3	4	5	6	7	8	9	10

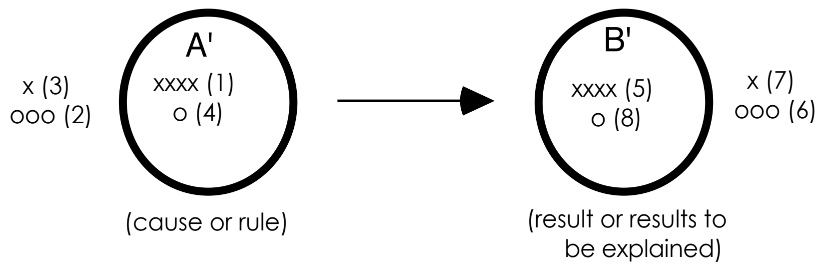
Communication

B	x	x	x	x	x	6	x	x	x	x
C	x	x	x	4	5	6	7	8	x	x
D	1	2	3	4	5	6	7	8	9	10

I would have also told you something, (albeit less) if I only told you that it was between 4 and 8 (see line C). I would have reduced your uncertainty by half. I would not have told you anything at all if I told you it was between one and ten (line D). Your uncertainty would not have been reduced at all. In this last example it is also the case that I would have been absolutely correct no matter what happened no matter which was the right answer. Additionally, you could never say that I had told you that some number would be wrong when it was actually right. This impossibility of “error” explains, of course, why these correct but uninformative utterances are so popular. Philosophically these uninformative prophesies are said to make no "risky predictions." They cannot be disproved (in the sense of having said something that was wrong when it was right) because they predict everything. Science demands that a theory make a risky prediction or be falsifiable, because you cannot be right (i.e., communicate information) if you cannot be wrong (i.e., some conceivable outcome would prove you wrong). In other words you cannot claim to be right if you have not reduced uncertainty. Science is interested in the size of the x'd in area in the preceding figure. Theories which make predictions that produce big x'd in areas are good theories, those which produce less x'd in areas are less acceptable. Let's face it, advisors are not much good if they tell you that anything you think of is right. They gave you no more new information than a tape recording of your own voice.

4. Minimal Error

As is illustrated in the following figure, explanations like decisions (see Chapter 11 Section II.) have four possible occurrences.



(1) Elements which should be in the cause or rule are in the cause or rule (x's contained within set), (2) elements which should not be in the cause or rule are excluded from the cause or rule (o's excluded from set), and the two types of errors which are (3) elements which should be in cause or rule which are not (x's left out of set) and (4) elements which should not be contained which are (o's included within set). Similarly, for the results: elements which should be covered by the explanation are covered (5), elements which should not be covered are excluded (6), and the errors which are elements which should be covered which are not (7), and elements which should not be covered which are (8). Science is the process of developing better boundaries for the two sets.

a. Parsimonious

Explanations must be parsimonious. The boundaries of A and A' must be defined in such a way as to exclude as many elements which do not belong (i.e., 4) as possible. There must be the minimal number of causal elements or predictor rules because the most productive explanations are the simplest. Rube Goldberg machines are mechanically unparsimonious. Wildly complex theories do not clarify problems, they make them worse. For example, if I look out my window and "see" a prowler and then look again and see a bush in his place, I can assume a unparsimonious explanation by contending that the prowler changed into a bush or I could accept the more parsimonious explanation that I was mistaken the first time I looked out the window. If a child misbehaves you may assume that the child: has a need to self-actualize; a need to return to the primitive inorganic state recalled by the cellular substance; has a mean streak; is possessed by the devil; or has obtained consequences for that misbehavior which are maintaining it. The principle of reinforcement is a single straight forward notion which accounts for a very wide range of behavior in a wide variety of species and therefore provides a very parsimonious explanation. An alternate example which illustrates a successive loss of parsimony is provided in this sequence of increasing complex descriptions for the same event: a key peck occurred, the pigeon pecked the key, the pigeon learned to peck the key, the pigeon learned to peck the key in order to get food, the pigeon learned to peck the key in order to solve its need for food etc. Science has relied on simple explanations of wide generality more than complex explanations of specific phenomena. It has resisted complication or unparsimonious explanations.

b. General

Explanations must be general. The boundary of B' must contain as many of the x's (5) as possible. As many events as possible must be explained. If you understand architecture and the rules of physics you will be able to build a variety of structures in a variety of situations without any collapsing. Einsteinian physics explains more than Newtonian physics. The principle of reinforcement is one of the most general principles of psychology. The more phenomena covered and the wider the range the more general.

c. Optimal Tradeoff

In sum, there are two types of errors on the rules sides and two types of errors on the results sides. Clearly having no errors on either side is best. But given that there will be errors, science attempts to optimize its task. The idea is to explain the maximum number of phenomena (minimize 7) while minimizing the number of rules necessary to accomplish that end (minimize 4). Science could be seen as trying to explain more results with less theory. Each scientist that moves our knowledge in that direction succeeds. A false alarm or the inclusion of an unnecessary theoretical element on the rule side (4), is considered worse than having a necessary one missing (3). Secondly, it is considered worse to have a restricted range of applicability (7) on the results side, than explaining something incorrectly (8).

5. Systematic or Principled

An explanation must be systematically and coherently integrated within a larger frame of reference or paradigm. It is the interlocking and cross validating nature of the processes, explanations, and observations that are labeled truth. It's easy to be eclectic and choose whatever explanation fits the situation for now, but it should be remembered that the freedom of eclecticism is the freedom of ignorance over knowledge. It has all the advantages of theft over hard work. A million different unrelated explanations for a million different phenomena is no explanation at all. Anyone can make up a story to specify the cause of one isolated event. Understanding is the ability to explain a million phenomena with one explanation. Productive wisdom must have both the explanation for the local effect as well as a systematic way to have chosen that explanation.

6. Comprehendible

An explanation to be useful must be understood by the community. It must be presented in such a way that as many people as possible understand it. Unfortunately, as a science matures fewer and fewer participants qualify to understand the most recondite knowledge of a field. In fact, progress can be measured by the distance from the lay.

7. Pragmatic

An explanation must in some way help; it must make a difference; it must be useful. Explanation cannot be little more than verbal smoke but rather must connect to prediction, control, and synthesis of the phenomena and must provide a way to manage a meaningful amount of the variance in nature.