Ironically, the reemergence of issues banished by Galileo can be grasped *only* by the application of the method of science. Since in dealing with these issues that method receives its severest challenge, it behooves us to examine it carefully. To this end, we discuss a modern view of experimental science.

A modern view of experimental science

First of all, why go into this?: Most physics texts hardly do. We review the method of science carefully to avoid two pitfalls.

The first one: Since, the conclusions we later come to with quantum mechanics can be intellectually unsettling, some are tempted to *mis*identify them with speculative philosophy. By doing so they may comfortably, though incorrectly, dismiss these conclusions as "just opinion" or unprovable mysticism instead of accepting them as reliable science that logically compels consensus.

Then there's a more serious hazard: On seeing a rational science like physics reveal such weirdness in Nature, some have become excessively uncritical and accepting of less than rational mystical ideas.

To avoid these pitfalls we carefully spell out the logical criteria we agree to use for accepting an idea–or a "theory"–as reliable science. *We want to agree on our rules of evidence* [7].

"Theories": First of all, in science, the word "theory" does not imply that a concept is speculative or uncertain. Even the most solidly based scientific doctrines are called "theories [8]."

We want to agree not only on how the method of science works but when it applies--and when it does *not* apply. We must therefore talk of nonscientific concepts as well as scientific. These can include moral injunctions, religious beliefs, philosophical positions, political or economic convictions, myths--*anything!* Lacking a better single word to encompass all of these, I use "theory."

7This exploration of the criteria for reliable science is the "gun safety" promised in the Preface.

8A very tentative idea might be called a "hypothesis" or a"speculation." The presumptuous word "law," as in "law of Nature," is not used for ideas developed in modern times.

Here are some examples showing the wide range of theories I have in mind. It's pretty obvious which you would call reliable science and compel consensus, and which surely don't qualify. Our point is to examine how we make that reliable science decision. We want to see just how we decide whether or not a theory satisfies our rules of evidence.

Galileo's theory of falling
Aristotle's theory of falling
Germs can cause disease
Newtonian mechanics
Any religion (including devout atheism)
Astrology
"All men (people) are created equal and are endowed..."
Vitamin C prevents colds
The Toothfairy theory
Einstein's theory of relativity
Extra sensory perception (ESP) exists
Freudian (or Jungian, or Skinnerian, etc,) psychology
Quantum mechanics

For starters, we've already discussed Galileo's and Aristotle's theories of falling. Galileo's checked out, it compelled consensus, we therefore accept it as reliable science. The predictions of Aristotle's theory, when put to the experimental test, failed. That theory is wrong science.

What about religions? Clearly, they do not compel consensus. They are thus not reliable science. Are they then wrong? No, there is no way in which a religion can be ***proven*** wrong. Our description of the method of science should make clear that the method is not applicable to such theories.

For some theories the method of science logically compels consensus, for some, it compels rejection. Other theories we may logically accept ***or*** reject--as an individual choice. To some we may be firmly committed on, say, moral grounds--but not be ***logically*** committed. How do we make these distinctions? Just what rules do we use to determine whether something is "reliable science"?

<u>Descriptive, not *pre*scriptive:</u> This is important: I don't want to prescribe the method we ***should use*** for deciding what is reliable science. I'm trying to do something harder: to describe the method we actually ***do use***.

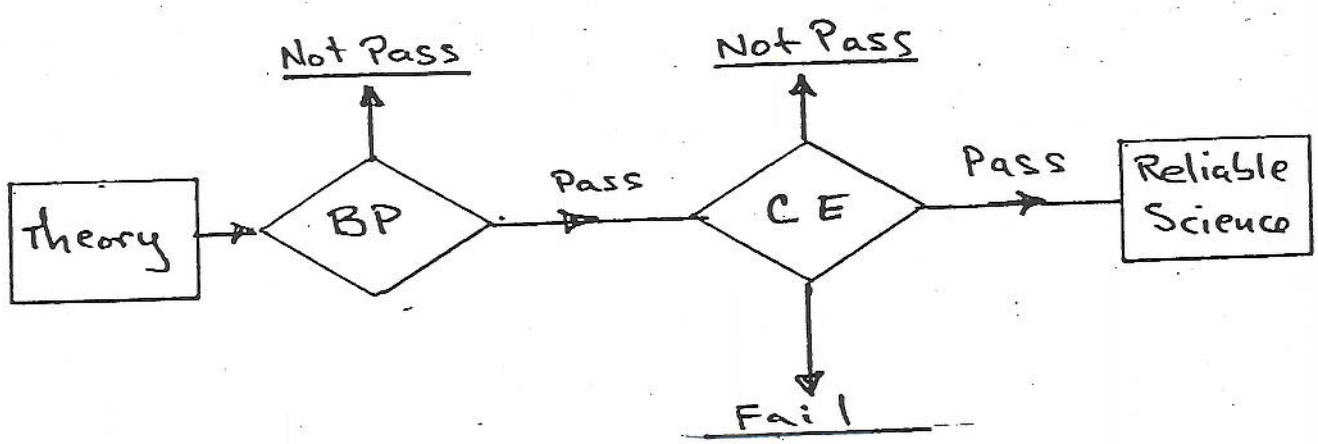
A test of my success will be whether a few pages from now you agree that this is indeed the way you would classify a theory as being--or not being--reliable science. I present an oversimplified view of a complex issue; it's called "epistemology," how we know things. Please be a bit sympathetic. It's easy to think up situations where the recipe (or the examples) I give are ambiguous, or where other considerations are also relevant. Some of the things I leave out of the simple picture I do mention at the end of our discussion.

<u>The "reliable science filter":</u> To separate theories which are reliable science from theories which are not, we want a "filter" through which only reliable science can pass. Let's start by agreeing to a working definition of a "reliable science": ***A reliable science is a theory which can compel consensus.*** It is thus a theory which can convince essentially everyone that its predictions can be relied upon. If a theory meets this criterion, it is, by our definition, a reliable science. If not, it is not. A correct theory may at some stage not be established as a reliable science, and a theory considered reliable science may later turn out to be incorrect. We use a social definition for our filter rather than an absolute one. This must be so; science and its application is a social phenomenon.

If our reliable science filter works well, Galileo's theory of falling and the theory that germs can cause disease, for example, must surely pass through. Aristotle's theory of falling must fail to do so. Since there is no way to logically compel consensus on a religion or a moral injunction, such theories should not pass our filter--but not for the same reason that Aristotle's theory of falling does not pass. Other types of theories seem to permanently defy consensus, Freud's (or Jung's or Skinner's) theories in psychology, for example. These therefore should not be classified as reliable science in our strict sense.

We will illustrate a filter for reliable science by sorting out such examples. We consider only fairly black and white cases. Let's not worry about the grey areas. Remember the object of this exercise: we want to demonstrate quantum mechanics to be reliable science in spite of its weirdness. Trust me, the operation of the filter will not then be ambiguous.

<u>The two tests:</u> For a theory to be considered reliable science, we require it to pass through two stages of our filter; it must pass two tests: "*<u>B</u>old <u>P</u>rediction*" and "*<u>C</u>hallenging <u>E</u>xperiment*." Here's a diagram of our filter.



In the box at the left you can imagine a theory awaiting the tests it must pass before becoming accepted as reliable science and moving through to the box at the right. The two tests it must pass are represented by the diamonds labeled "BP" and "CE." A theory which passes both tests gets through the filter, and is reliable science. Let's describe the tests and how a theory passes them, fails them, or neither passes nor fails.

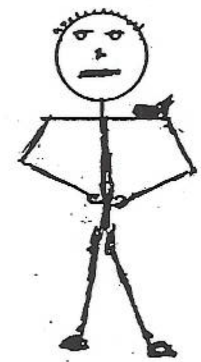
The first test: Bold Prediction

A prediction provided by a theory is bold if it ***endangers*** the theory. By making a bold prediction, a theory risks being shown false, being falsified. For a prediction to be bold it must be testable. (Smith's stock market theory predicts ABC Corp. will ***surely*** go down 4 points next Tuesday. That's a testable prediction. It's very bold; if it turns out wrong, Smith's theory is falsified.)

Predictions with a high degree of uncertainty are less bold. (Jones' stock market theory predicts ABC Corp. will ***likely*** go down somewhat Tuesday. That's a testable prediction, but it's not terribly bold; if it turns out wrong, Jones' theory is merely weakened, not falsified.)

Untestable predictions do not endanger a theory at all. (Brown's stock market theory predicts that investor uncertainty will have the major effect on the price of stocks next Tuesday. That's probably not testable, it's hardly a bold prediction. Brown's theory can't be proven wrong, it's not falsifiable.)

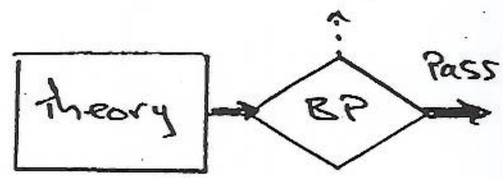
Any theory providing reasonably bold predictions can be considered a "scientific theory." It need not be a correct theory; it's predictions may be wrong. A scientific theory--right or wrong--is any theory which, by bold predictions, provides a recipe for its own refutation. To even be considered as a candidate for reliable science, a theory must stand boldly with a chip on its shoulder challenging would-be refuters.



This "chip test" essentially asks the following question: "Does the theory predict an observable result which might force the theory's abandonment or modification?" Or saying the same thing compactly: ***"Is the theory 'falsifiable'?"*** For any ***scientific*** theory, the answer must be yes. A theory that makes no bold predictions is untestable. It can't be falsified. It can't possibly be shown to be wrong. By the same token, it can't give evidence of its correctness.

Since this is an important point (and we have a tricky word), let me risk possibly needless repetition. A "falsifi***able***" theory is ***not*** a false or wrong theory. It's theory which makes a definite prediction--and therefore ***might*** be wrong. A non-falsifiable theory makes no testable prediction. A theory which makes no such bold predictions is safe from refutation. By the same token, it can never compel consensus.

Soon we discuss the actual experiments: the second test a theory must pass in order to become reliable science. But first, let's consider some clear-cut examples, first, theories which do pass, and then theories which do not pass our Bold Prediction test.



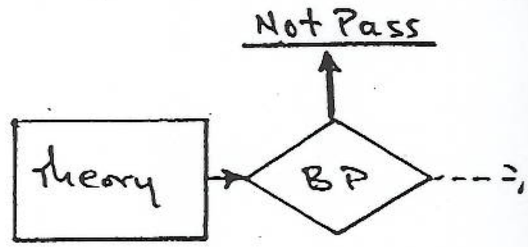
Passing the Bold Prediction test: Galileo's theory of falling predicts all bodies, both light and heavy, fall at the same rate as long as resistance is negligible. The theory even tells precisely how speed increases as a body falls. These are indeed testable predictions. Since if they were wrong, Galileo's theory would have to be abandoned or modified, it passes the Bold Prediction test with flying colors. It is therefore a scientific theory.

Aristotle's theory also makes bold predictions (though not quite as bold). It predicts that heavier objects fall faster than light, and all objects fall at a constant speed. Like Galileo's theory, it passes the Bold Prediction test. It too is therefore a scientific theory. (As we know, when subjected to Challenging Experiments, our next test, Aristotle's theory turns out to be wrong. But since it provides Bold Predictions, it's a scientific theory nonetheless--it's just a ***wrong*** scientific theory.)

Look back at our list of theories. Which of them also pass the Bold Prediction test? No question about the Germ theory, Vitamin C, Relativity, and Quantum Mechanics. They all make clear predictions. The theory that ESP exists predicts people can acquire information without input to any of the normal senses. Procedures to test ESP are readily outlined. ESP passes the Bold Prediction test. So does Astrology. While newspaper horoscope columns are usually written ambiguously, and therefore make no bold predictions, astrologers at times have provided specific and testable predictions. Not all theories we call "scientific" are correct, they merely provide testable predictions.

The Toothfairy theory predicts that if you put one of your baby teeth under your pillow, the fairy will put a dime in its place for you to find in the morning. (At least when I accepted this theory it was only a dime.) With later data I falsified this theory. I include it here to emphasize that being "scientific" in this present sense does not endow a theory with great status.

It could almost go without saying that the testable predictions of any acceptable theory must be ***logically consistent***. If a theory made two testable predictions which were logically contradictory (that is, they said opposite things) they could not possibly both be correct. Such a theory falsifies itself. Showing a theory to be logically inconsistent immediately rules it out. It does not warrant the effort of experimental test until the inconsistency is corrected.



<u>Not passing the Bold Prediction test:</u>

"Failing" the Bold Prediction test would be the wrong word. A theory which make no testable predictions generally doesn't even try to. *It doesn't take the test.* Look at some examples.

Consider a theory which is a religion. Ask a devout believer: "What experimental observation would force you to abandon or modify your religion?" You would be assured that no such observation is conceivable--their faith is absolute and all-encompassing. The predictions made by religions, or by atheism (that there is a heaven, for example, or that there is no such thing) are not bold because they are not testable. A religion is not falsifiable. Religions therefore do not pass the first stage of our filter. They are not scientific theories. And, obviously, they don't compel consensus.

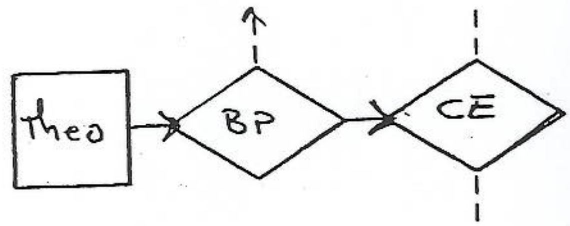
Likewise, no experiment could ever logically force one to abandon the Declaration of Independence's: "All men (people) are created equal..." In a certain sense, it has a ***higher*** status than any scientific theory. Religions and moral precepts can be invaluable as worldviews and ethical guides, however, they are not scientific theories, they do not pass the Bold Prediction test. They don't try, they don't take it.

Other widely used theories do not pass the Bold Prediction. Many Freudian (or Jungian or Skinnerian) psychologists, for example, would assert that ***all*** human behavior is encompassed by their theory. ***Any*** observation could be explained within the theory. No conceivable observation would force its abandonment. These theories are not falsifiable. The same observation holds for the free-enterprise economic theory (or Marxist economic theory): there are no observations which would force holders of those views to abandon them. And just looking around, it's obvious that such theories do not compel consensus. In this ***strict*** sense, at least, these are not scientific theories. They should not be considered reliable science--for which the ability to logically compel consensus is the ultimate test.

But scientific or not, psychological theories nevertheless provide effective therapeutic techniques and offer insight into human behavior. Economic theories serve effectively in the management of economies. Not passing the Bold Prediction test, in itself, does not denigrate a theory, and passing does not necessarily confer high status. Remember, Freudian psychology and free enterprise economics do not pass, while astrology and the Toothfairy theory do.

A question the Bold Prediction test does ***not*** answer: Are the predictions of the theory ***correct***? If a theory passes the Bold Prediction test, it is indeed a "scientific" theory, but it is not necessarily a correct scientific theory. Its testable predictions may turn out to be wrong when they are in fact tested. The theory must pass a second test before it can be considered ***reliable*** science.

The second test: Challenging Experiment



Theories passing the Bold Prediction test and coming to the second test, Challenging Experiment, are vulnerable. They have made ***testable*** predictions. They are therefore in danger of being shown wrong, being falsified.

In the Challenging Experiment test the theory, is hit with the brute facts of Nature. It must survive every blow.

"Experiment" is a crucial concept here. Let's define it carefully.

> **An "experiment" is a demonstration <u>contrived to test</u> a theory. A good experiment <u>convinces essentially all observers</u> as to the facts displayed.**

Let's look at some important pieces of this definition.

<u>"...contrived to test...":</u> What is seen in the world around us is, as a rule, not simple enough to provide a critical test of a theory. Too many influences are usually involved for the theory to handle. An experimenter typically contrives an idealized, "simple" situation in which only a few factors are present[9].

Galileo's theory of motion treated the simple, idealized case where resistance was totally absent. To eliminate ***most*** resistance, Galileo experimented by rolling balls along "unnaturally" smooth planks. Today's experiments can be far more "unnatural." Often attaining the simplicity is neither easy nor cheap. To test the predictions of the fundamental theories of matter, we build multi-billion dollar accelerators to slam one proton into another at energies vastly greater than that in any proton collisions which happen naturally on earth.

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[9]Sometimes, we must interpret "experiment" to include highly specific and detailed observations. Astronomy is a prime example. The essential ideas are the same.

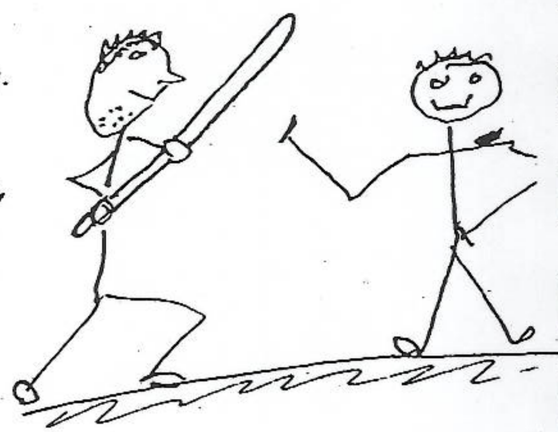
"...convinces essentially all...": A second part of our definition of a good experiment is that the demonstrated facts must be indisputable, plain for all to see. The issue at this point is not whether the observations are in accord with the predictions of the theory; it's whether all observers of the experiment can agree on what happened. In a good experiment, the displayed facts must be convincing.

Usually a crucial aspect of being convincing is ***reproducibility***. A good experiment should be repeatable, and the same results should be obtained by any competent experimenter.

Must the displayed facts always be convincing to ***any*** observer? That's unrealistic. It is generally sufficient that "experts" be convinced. Most modern scientific experiments fall in this category. However, in such a case, we must be careful about our "experts." Expertise must not require prior conversion to a particular view. ***Skeptical experts must be allowed and be convinced.*** (The skeptics are the most important!)

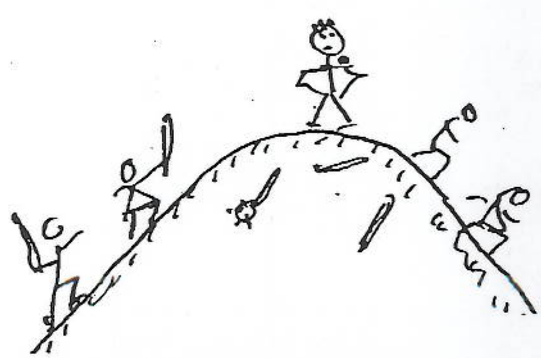
There is, admittedly, a "soft" issue here. In the last analysis, you must choose your experts. This usually poses no problem for clear-cut scientific issues, we then generally agree on our experts. And for the gray areas? Let's just recognize that gray areas exist and, for now, ignore them.

The method of science is hard on theories: By making a bold prediction, standing with a chip on its shoulder, a theory challenges any would-be refuter. An experiment takes up that challenge. A good experiment confronts the predictions of the theory with observations selected to be the most challenging, the most likely to disprove the theory. To *test* the theory, a good experiment must *try* to falsify the theory. If the experimental results accord with the predictions, the theory withstands the challenge. It gains reliability each time it successfully passes a challenging test.



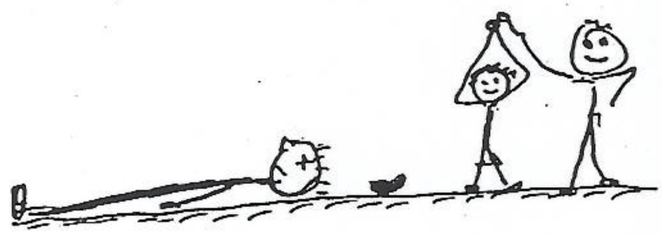
For a theory to be accepted as truly reliable science, it must survive repeated confrontation with experimental data. It must pass through the filter many times. It must make many predictions which turn out to be correct when tested.

Moreover, a theory must be able to pass challenging experimental tests no matter who does the experimenting. Even those (especially those!)



who *want* to disprove the theory must have a chance at it. The dramatic outcome for an experiment, bringing great prestige to the experimenter, is showing that a well regarded theory is in error.

In spite of many correct predictions, a single clear-cut refuting experiment falsifies a theory. It forces its modification or abandonment. ***The experimental method is hard on theories.*** One strike and you're out!

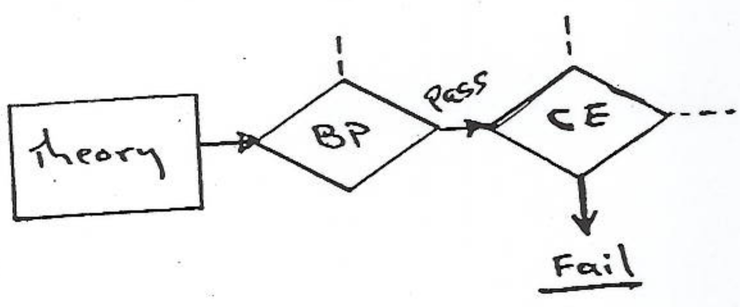


With his demonstrations of balls rolling down planks, Galileo claimed to have refuted Aristotle's entire theory of motion. Today's physics lecture-room demonstration showing a feather and a coin to fall at the same rate in a vacuum dramatically does this with a single clear-cut experiment.

<u>Not</u> passing the Challenging Experiment test

Theories passing the Challenging Experiment test become reliable science, and we'll talk about that shortly. But first, let's mention ways in which theories ***don't*** pass.

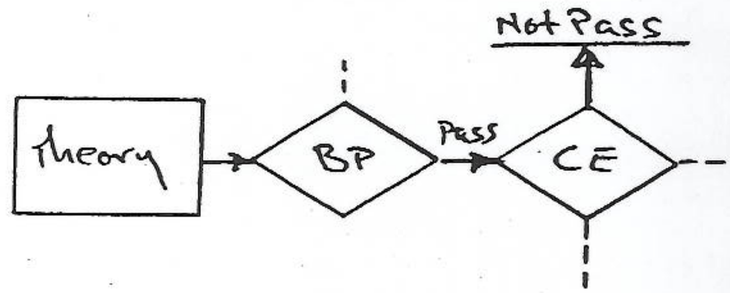
<u>Failing the test (incorrect theories):</u> The simplest way for a theory not to pass the Challenging Experiment test is for it to ***fail*** the test. A theory fails when an experiment compares one of its predictions against what actually happens in Nature and finds the prediction to be wrong. That was the fate of Aristotle's theories of motion.



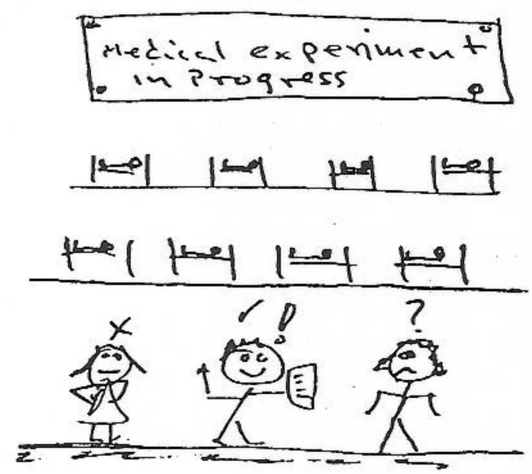
A serious, clear-cut failure may consign a theory to the waste basket. This happens frequently and illustrates the efficiency of the scientific method. Imaginative scientists toss out many of their own theories, usually by testing their predictions against already-done experiments.

Sometimes a theory works somewhat. Many of its predictions are correct, but others may be inaccurate, or it may miss the mark widely under certain conditions. It then fails the Challenging Experiment test. But if it's better than anything else around, you don't just abandon it. A patch-up is attempted. A theory's basic assumptions can be modified somewhat, or its range of claimed validity can be restricted. Now put through the filter again, it may pass.

Galileo's Principle of Inertia is a good example. It predicted that without resistance a horizontally moving object would move forever. "Horizontal" to him meant along the surface of the earth. Since for the short distances Galileo worked with the distance along the earth's surface is almost a straight line, that was a good approximation. But it's wrong, and does not work at all for the motion of planets, for example. Newton corrected the Principle of Inertia a few decades later to say that an object without impressed force moves forever in a ***straight line.*** [10]



<u>Not passing the Challenging Experiment test (inconclusive experiments):</u> Especially in complex fields where experimental situations cannot be simplified, medical research, for instance, there is often difficulty in isolating the particular effect to be studied. The role of various factors in determining the experimental result is frequently unresolved--or even in dispute. A theory not clearly passing experimental tests remains a theory in question. As a rule, interesting theories don't stay that way long, particularly in the more straightforward sciences like physics. As time goes on, experiments improve, and agreement develops. Theories tend to become either increasingly reliable or are falsified and discarded or modified.



That's not always so. For example, it has long remained controversial whether various "alternative" medical theories work only by the placebo effect--because patients believe they work. (One can envision experimental tests of these ideas, but there seems little motivation to test them--both on the part of the believers and the skeptics.)

The case of "paraphenomena" warrants special consideration. We hear amazing reports of things beyond the range of normal experience: ESP, precognition (knowing the future), mental metal bending, and spirit communication. If even the tiniest bit of such stuff were real, it would be the tip of the biggest iceberg imaginable. It would profoundly change our entire scientific worldview.

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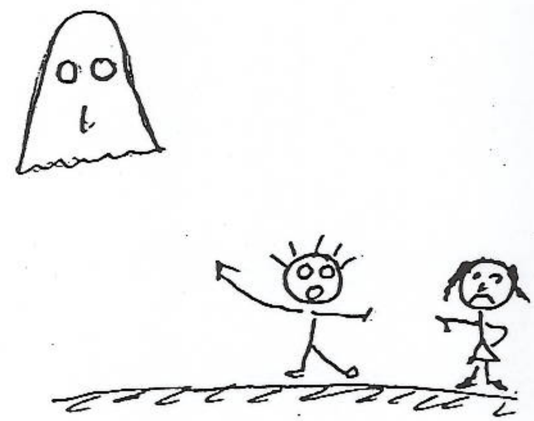
[10] The Principle of Inertia was corrected again 250 years later by Einstein to make the theory work at speeds close to that of light and over cosmological distances.

I'm particularly sensitive on this issue because the quantum phenomena we soon come to is today frequently cited to give a scientific underpinning to various paraphenomena. Or else the general argument is made: "Since *physics* demonstrates a weirdness in Nature with quantum mechanics, we should not be so skeptical about other strange things." I must admit some tiny measure of validity to such an attitude–we'll discuss it later. But the arguments involving quantum mechanics and paraphenomena are usually far-fetched, or worse.

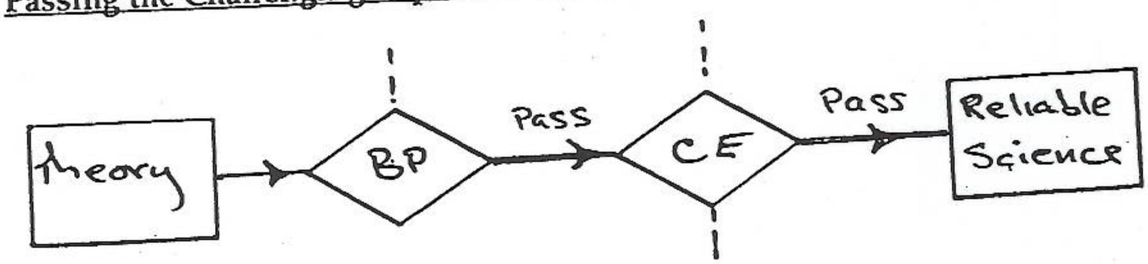
Unfortunately, to date, paraphenomena can be convincingly demonstrated to only a fraction of those who try to witness it, and almost never can it be displayed to skeptics. (Unfortunately? Yes, I'd love it to be true.) So far not a single such phenomenon has passed the Challenging Experiment test[11]. This, of course, does not prove that no paraphenomena occur. You can't prove a negative result.



There are honest proponents of the existence of paraphenomena, and some try to be sound experimenters. These workers generally agree that positive experimental results have never been demonstrated in a way that can convince a major fraction of knowledgeable, open-minded skeptics. They would agree with me that theories professing such phenomena must still be assigned a "not pass" status on the Challenging Experiment test.

Most scientists are probably less tolerant than I am. Paraphenomena have been in the tentative niche long enough, they say, and point to the large number of "demonstrations" exposed as errors, delusions, or frauds. If there were anything to this stuff, they claim, there should by now be stronger evidence. They would assign all paraphenomena the status "incorrect theory"– or something worse.

Passing the Challenging Experiment test



[11] What of all the reports of strange phenomena we read about in the paper or see on TV? Keep in mind a law of survival in the media jungle: The reporter who, given an exciting lead, turns it into a factual but dull story doesn't last long.

Theories which pass the test of Challenging Experiment by making ***many*** clear predictions, ***none*** of which has ***ever*** been shown wrong, have successfully withstood many attempts at falsification. We rely on them. ***They compel consensus.*** For a theory there is no higher status.

But such theories are still not certainties. Strictly speaking, we should call them "***tentatively*** reliable science." Scientific theories can only be tentatively reliable at best. No matter how many times a theory withstands experimental challenge, it is never ***proven*** true. No amount of experimental testing can ever do that. Many theories in common use are so well tested that we hardly think them tentative, but the case is never closed. A future experiment might conflict with the theory's predictions forcing the theory's modification or abandonment. The scientific method does not presume to arrive at "Absolute Truth."

In a "simple" science, one whose theories can be clearly specified there is substantial consensus. There are, for example, essentially no "schools of thought" in physics, except on the research frontier. There is general agreement on the fundamentals. And the schools of thought that do exist on the research frontier tend to get resolved in a relatively short time[12].

Some theories are extremely well established: the theory that germs can cause disease and Einstein's theory of relativity, for example. Without some compelling new evidence or insight, voicing doubts about these risks the crackpot label[13]. (Quantum theory might be in this class too—except for the weird worldview it demands.)

<u>Accuracy:</u> In introducing the Bold Prediction test, we noted that predictions stated with large uncertainty are less than bold. The more precise a prediction, the bolder. A theory precisely predicting the price of General Motors stock weeks in advance is bold because it readily admits experimental falsification. If when put to the Challenging Experiment test, such a theory is consistently correct, we become convinced that its fundamentals are sound (though probably illegal).

Likewise, a most convincing aspect of modern theories and experiments in the physical sciences is their ***precision***. When a theory predicts

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[12] There are, of course, long-standing disagreements on such non-scientific issues as to which areas are the most worthwhile to study.

[13] I mean Einstein's "*Special* Relativity," which we later discuss. Einstein's "*General* Relativity," his theory of gravity, has met every test, but it is still the subject of critical examination.

the result of a measurement will be: **2.0023193044**, and it's actually found to be **2.0023193048**, (Compare these two numbers!) you've got to be impressed[14].

In a mature field, two competing theories sometimes give precise predictions which are so close that accurate measurements are needed to distinguish between them. But even today, experiments with twenty percent error, or even more, provide important tests.

<u>Consensus allows progress:</u> Without consensus, arguments on old issues go on and on. New ideas can further fragment the field. Compelled consensus, on the other hand, permits progress. Issues become settled, and the field moves to address those that then become ready for attack. Unlike philosophers, scientists are not primarily interested in exploring profound questions, they are motivated to resolve ***answerable*** ones. If a question seems unanswerable (too profound?) it is usually dismissed from science and assigned to the philosophers. Science ***demands*** progress.

Some BIG issues I've left out

The method of science presented here bears a relation to actual science similar to the one a Sherlock Holmes story does to an actual police investigation. The real world is complicated[15].

Theories are always affected by the observations the theorist chooses to encompass: Which phenomena does he consider important, which does he idealize away? (Aristotle emphasized resistance to motion, Galileo chose to ignore resistance and treat unimpeded motion.) In the long run, the choices that lead to the most effective theories are the best. There's no simple rule. It's instinct, trial, and error until the theory passes all challenges by experiment. And it's not only the subjectivity and intuition of the theorist that affects the course. The experimenter's choice of experiments which experiments to do and how she interprets them are affected by her view of the current theories. When you add people to the picture, it becomes complicated

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14This is the quantum mechanical prediction and the experimental measurement for the so-called "g-factor of the electron." The only discrepancy—in the tenth decimal place!—is within experimental margin of error.

15Analyzing these complexities, some modern philosophers have provided valid critiques of the methods of science, others have become famous for their largely absurd views.

According to our model, the only condition a theory must meet to become reliable science and compel consensus is to pass through our filter many times. While this is an absolutely necessary condition, it is not a sufficient one. There are further subjective issues which are not easy to articulate. But let me try.

<u>Simplicity:</u> The fundamental assumptions of a theory should be few and simply stated. It is amazing how often this aesthetically desirable feature of simplicity, taken as a hint, leads to the theory which works. (Einstein said the most incomprehensible thing about the universe is that it is so comprehensible.)

<u>Integration:</u> We don't want a lot of little theories, one for this and one for that. The more phenomena a theory explains, the better we like it. The ultimate goal is a single overarching theory encompassing *all* of Nature[16].

<u>"Satisfying explanation":</u> This is the trickiest point of all. We seek more than predictions. We yearn for an "*explanation*" of what's going on in Nature. Trouble is, I'm not sure what that means. But it will be a central issue for us. Quantum mechanics is a theory which predicts perfectly, but the "explanations" it provides are not satisfying, they're ridiculous.

Have I succeeded?

Early on I said that I did not want to tell you how you *should* decide on whether to accept a theory; I wanted to describe how you *actually* do decide. Have I succeeded? Of course we rarely make such decisions for ourselves. We let our chosen experts make them. For example, we take the drug prescribed. So have I described the way you expect your experts, say the drug researchers, to make such decisions?

Can you conceive of a better way for deciding whether to accept a theory? Since our definition of "theory" was broad (it included ideas for which the method of science did not apply) that's not the question I should ask. I rephrase the question: Can you conceive of better way to convince skeptics to accept a theory--to compel a consensus? I can't.

16We don't expect a theory that can predict everything in any practical sense, but an underlying theory beyond whose scope no phenomenon in Nature depends, in principle, seems possible in the not distant future. It is referred to as the TOE, the "Theory of Everything."

A comment on matters beyond science

Physics is the science dealing rigorously with fundamentally simple entities (or with simple models of complex entities). Because of that, in physics a theory's assumptions can be specified in complete detail. The rigor of mathematics can then be applied to deduce predictions. If a result conflicts with the theory's predictions, the theory must in some way be wrong. A single conclusive experiment can force all to agree that the theoretical structure must be changed. In physics the scientific method readily compels consensus. With such consensus, the field can progress rapidly to the *next* problem.

At another extreme, the social sciences deal with extremely complex issues, assumptions can rarely be completely defined. The vagueness of ordinary language must usually be tolerated in arriving at predictions–to the extent that predictions are made at all. The scientific method we have outlined can only be used in its most general form. Wide consensus is rare, schools of thought abound, and progress is necessarily slow.

In a larger sense, science of any kind, physical or social, is not the most important game in town. Most of the issues in our lives are far too complex for a scientific approach. In these spheres, science provides some input data, a model for clear thinking, and clues for speculation. But we must ultimately rely on perceptions not subject to experimental test or even to rational evaluation. In our final chapters we will see that the method of science confronts us with an amusingly similar situation.