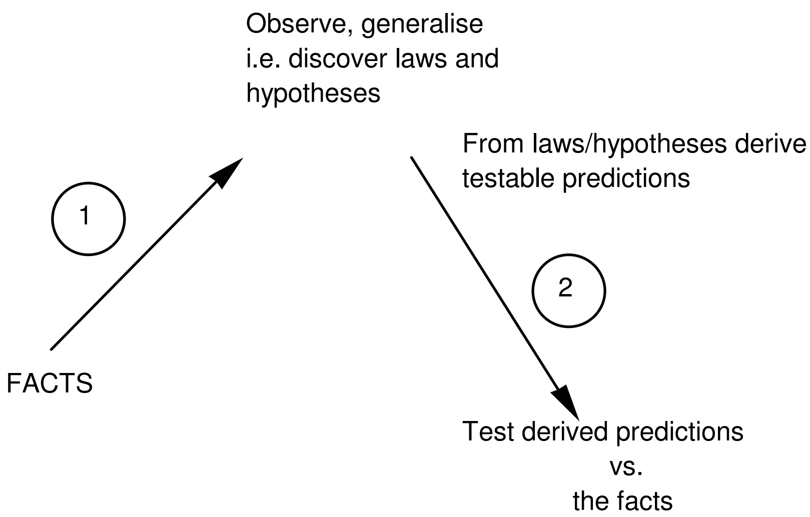
7 Sir Karl Popper's Attempt to Save Scientific Method

I would like you to consider again for a moment the traditional story of scientific method: (fig. 1) Firstly we have a generalisation or induction of the facts which together form laws or theories which are just summaries of those facts. One then tests the predictions derived from the theory, if the tests results 'match' the predictions we have further confirmation of the theory; if they do not match the prediction, we have to revise or discard the theory.

FIGURE 1
TRADITIONAL METHOD STORY



We have also discussed a little bit about the history of these ideas, from Aristotle up to this century, and I suggested to you that what we have learned about the 'theory loading of facts' really does a great deal of damage to this view. If you go out to generalise, or to observe, you're only going to be able to see or to generalise within your own framework, within your own conceptual grid. The **types** of facts that we are able to generalise about are as it were, pre-given. Another point is that we have already seen that theories are not just summaries of hard fact; theories are culturally shaped, shaped by background assumptions, so there's always more in a theory than just a collection of bitty, hard objective, facts--assuming that such things exist.

So, there are difficulties with this traditional picture of method, and these difficulties have been recognised to a certain extent, only during this century.

Some historians of science who influence the kind of work that we do here, drew the conclusion that scientific method doesn't work. It is a nice story that is told, perhaps for rhetorical or political purposes, but the real nature of science, how scientific knowledge is generated and negotiated, must occur in some other manner. However, you should understand that in the philosophy profession, it isn't necessarily going to be an acceptable conclusion that scientific method is made redundant. Many philosophers of science, to a large extent starting with Karl Popper about sixty years ago, have taken the view that perhaps the old idea of method is indeed not workable, but that we can make it better. Perhaps to date we haven't had a very clear view of what scientific method is. If we could make our story more accurate and more up to date, then we could still believe that there is a scientific method, that it really works, and that it really explains what happens in science and what happens in the history of science. In effect it becomes a search for a replacement, for a modification of the old theory of method.

The most important, symptomatic and influential alternative picture of scientific method in our century was presented by Karl Popper in 1934. While in his early 30's, Popper wrote in German a book whose proper title should be "The Logic of Scientific Research". However, when it was published in English during 1958 a terrible mistake in translation occurred and it was published as "The Logic of Scientific Discovery" which as we shall see was a complete misconstrual of the German title, and of Popper's intentions.

Popper studied philosophy, physics and logic in Vienna during the 1920's and even though the Austrian empire had been dismantled in 1918 after World War I, Vienna was still one of the intellectual centres of Europe. For example, Freud and his followers worked there. Living in this kind of hothouse intellectual atmosphere, Popper was as a young man, very aware of a number of difficulties with the traditional view of scientific method, and he set out as an ambitious and very intelligent fellow to solve this problem--to give an alternative vision of scientific method.

Popper was aware of the existence of 'theory loading of perception', 'theory loading of facts'. In fact, he was one of the first people to discuss this in philosophy, and he says some amazingly radical things about theory loading of perception in the 'Logic of Scientific Discovery'. He knew that theory loading of facts really does cast some doubt on the idea that we just observe facts, generalise them and invent a new law. Because, surely, we are only going to see what we are already, as it were, 'gridded up' to see.

Another problem that Popper was aware of was that the history of science revealed some curious things about the notion of 'discovery'. What, after all, is discovery? In the old theory of method, discovery is what happens on the left hand side of the method diagram [Fig. 1]. This is where we discover a new law, or discover a new hypothesis. We observe, we generalise, and we arrive at a law or a hypothesis that nobody else has 'discovered' before. Popper did not have to face our criticism of this story [in Chapter Five] in which discovery is treated as a ' social construction', a consensually agreed shift in concepts with linkage to certain practices. However, Popper knew that there were many episodes in the history of science that didn't really fit the traditional picture. There are many famous examples in the history of science [although some perhaps are a bit mythical], where a great scientist didn't generalise, didn't go out and observe a lot of facts, generalise and discover a new law. Instead, the new law or the new theory just came in a creative flash of genius. For instance: the apple that hit Newton on the head; "Oh! I see it now; it's the theory of universal gravitation!". It didn't happen that way, but the fact that stories like this pass around demonstrates that discovery was not always understood to be a plodding generalisation of the facts.

Another example of this kind is Archimedes, the ancient mathematician, who was killed by the Romans in 212 BC. Archimedes discovered the principle of buoyancy: that you are supported in water by a weight of water equal to the weight of the volume of water that you displace. If you're denser than water, you sink, and if you're lighter than water, you float. He discovered this, as you may remember, while entering his bath, the bath overflowed causing him to exclaim, "Eureka, I've made a discovery!". It didn't happen quite like that, of course, but again in the story he wasn't generalising facts, he was having some sort of imaginative insight.

Another similar example is the curious six sided structure of the benzine ring, discovered during the 19th century. The corners of the ring are made of carbon atoms and it's very hard to imagine how the carbon atoms are bonded together, how six of them are bonded together in a molecule. But this ring-like structure was seen or discovered as an idea, as an hypothesis, by a chemist named Kekule, in a dream. He was working with the problem of benzine and he dreamt the answer. So it appears that the process of discovery doesn't always look like a generalisation of facts. Generalisation of facts is of dubious value anyway because of theory loading, which means that you are just generalising within your own particular theoretical framework.

The final thing that bothered Popper, and it bothered a lot of people in physics and philosophy of science at the time, was the idea that apparently, every once in a while, massive theoretical revolutions occur in science. Especially in physics. Every once in a while that brick wall of proven fact and theory is just ripped down. [Chapt 2 fig 3.] Or a huge hole is poked in it, and some different bricks, different groups of different facts, are put in its place. Scientific progress is not always putting one brick on top of another. Sometimes there occurs a dramatic change of structure.

The example that most bothered Popper was the problem of Einsteinian physics: Einstein's Special and General Theories of Relativity, especially the general theory of relativity, which gained great prominence after 1919 when a certain test was performed. Now, no amount of testing ever 'proves' anything in an absolutely definitive way: but, the physics community decided that Einstein had had the better of this test, as opposed to Newton. Einstein's theories thus gained credibility, but, if you look closely Einstein's theories were not just more bricks in the old Newtonian wall. Einstein's theory meant ripping out part of the wall and putting in some new bricks. For example, Einstein uses words like space, time, mass, and Newton uses words like space, time and mass, but these words mean quite different things in the two different theories. They are almost two different grids: Newtonian time isn't Einsteinian time and Newtonian space isn't Einsteinian space. This is not just a question of piling brick upon brick. There had been a revolution. The entire style and make-up of a large portion of the wall of scientific knowledge had changed.

The question we must now ask ourselves is why did this happen, how can this happen? According to the old story of method, it can't happen. This is because in the old story it's always proven facts that form the bricks: facts which are set down, and serve as the basis for laying more facts, more bricks, as you build up the brick wall, slowly and surely. In this story you just do not get wholesale 'revolutions' of the brick wall.
Popper, was very clever, not only technically, but in terms of seeing how one could become famous in the philosophy of science. Obviously one could become famous in the philosophy of science by saving scientific method and answering all of these questions. This is how disciplines work; problems develop and people make bids to get credit and fame by claiming to solve them.

So let's look at his answer. A lot of what I am going to suggest will perhaps appear peculiar, paradoxical, and even bizarre, but it is a set of answers to these problems and very interesting and brilliant ones at that. I actually think he is completely wrong-headed and still misses what goes on in science. He has produced another fairy tale, but it is certainly, from my perspective, a very clever fairy story and worth examining closely.

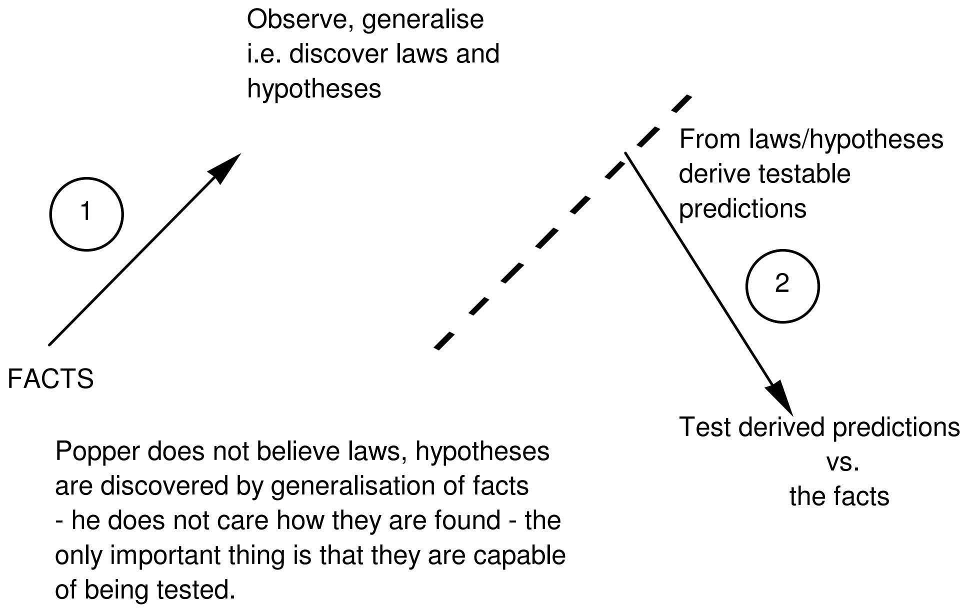
The first thing that Popper in effect says is, "I'm not interested in a method of discovery". This is what makes the translation of this book title so odd. He says, in effect:

> *as a methodologist I cannot tell you anything about the process of scientific discovery. I cannot tell you, [in other words], how to use a method to invent or discover laws and theories. There is no method for inventing or discovering laws and theories.*

Popper takes these problems and these criticisms on board, wholesale. If you like, he throws the whole left hand side of the traditional method story out of the window. (Too bad he didn't throw out the other half as well. He probably left that to us.) Popper would say that discovery is an issue to be elucidated by the researches of historians and anthropologists and psychologists, it is not a matter that can be reduced to a method. How did Newton discover gravitation? How did Archimedes discover buoyancy? It is, according to Popper, a psychological and historical issue, not just a matter of applying a method. Popper doesn't care how we produce a theory or law. He only cares about one thing: can your theory or law be put to the test. Is it testable. (fig. 1a)

FIGURE 1a
POPPER'S METHOD STORY

Popper cuts the standard story apart, to get his new story.
Method, for Popper, exists right of the dotted line.



Testable means, does your theory or law make predictions that can be tested. Popper's fundamental point at this juncture is that when you test the predictions made by your theory, you are not interested in positive evidence; you are not interested in evidence that shows your prediction to be true. In fact, ethically speaking, you shouldn't waste time looking for positive evidence that supports your predictions. Rather, your whole heart and soul professionally and ethically, should be committed to the search for negative evidence. You should be whole-heartedly committed to the search for evidence that shows that your predictions are false. Hence the name of his methodology. Falsificationism.

In fact, this is his definition of a scientific theory. A theory is scientific if it makes predictions that are capable of being found to be false. A theory is scientific if it is falsifiable. **Not if it is false; rather if it is capable of later being proven to be false.** You have to make a 'scientific' statement, a law, a theory, you have to say something that when put to the test, might be found to be false. If I say, for example, as my theory of the weather tomorrow that "it will rain, or possibly not rain", then I have not made a 'scientific' statement according to Popper, because I'm going to be proved right no matter what happens, it's either going to rain or not rain. My claim that it's going to rain or not rain is fairly broad, and fairly empty. However, if I say, tomorrow it's going to rain between a half a centimetre and a centimetre, then I've said something that might turn out to be true or might turn out to be false. It has a possibility of being false, and I've committed myself to a falsifiable statement. We don't know whether it's false yet, but it is falsifiable.

According to Popper, you have to be up-front, you have to make laws or theories that are capable of being proven false, and you've got to go out and try to see if they are. This, according to Popper, is how we learn things. Every time a law or a theory is shown to be false we learn something solid. We learn that the theory or law that we just had is false. Hence the somewhat paradoxical nature of Popper's method-- scientists are in the business of trying to prove their theories false.

Let's now look at the question of positive evidence. Why wasn't Popper interested in positive evidence? Popper had three main reasons for this, first of all: it's relatively easy to gather lots of positive evidence. Anybody with a theory and therefore with a perceptual grid, is going to find it very easy to see things and report things that support his or her own theory. There's something suspect about this, and part of the problem is ethical. Popper sees science as an enterprise that has to be pursued in the right moral framework, and it's just possibly corrupt, and certainly trivial to look for positive evidence.

The second point is a point in logic that was not new with Popper, but one which he stressed. The point is that no amount of positive evidence proves a law to be certain, to be absolutely true. You can pile up positive evidence, but it doesn't ever make your claim absolutely certain. But, if you find just one piece of negative evidence, so that you can conclude your law is false, you do know that for certain. That is, one piece of evidence can render a claim false, for certain. But no amount of positive evidence can render a claim true, absolutely true, absolutely certain.

Popper's third point was again a philosophical one and an ethical one: the search for positive evidence leads us away from the areas where we can actually learn something. Do we really learn anything by repeating tests that generate positive evidence.? No, we don't really learn anything by sticking with this, but when we look for negative evidence and we make the conclusion, in the light of negative evidence, that our law is false, we really know something. We know it's false!
Now, the question is, what does the history of science look like, assuming that scientists behave this way? (And that's a big jump, to assume that they do behave this way.) Well Popper has an answer for this. He has an answer

about how the history of science unfolds. And this is where it gets very interesting for us, because this is a possible story about the history of science. This is Popper's story [more or less his story of physics with the names changed for the time being]:

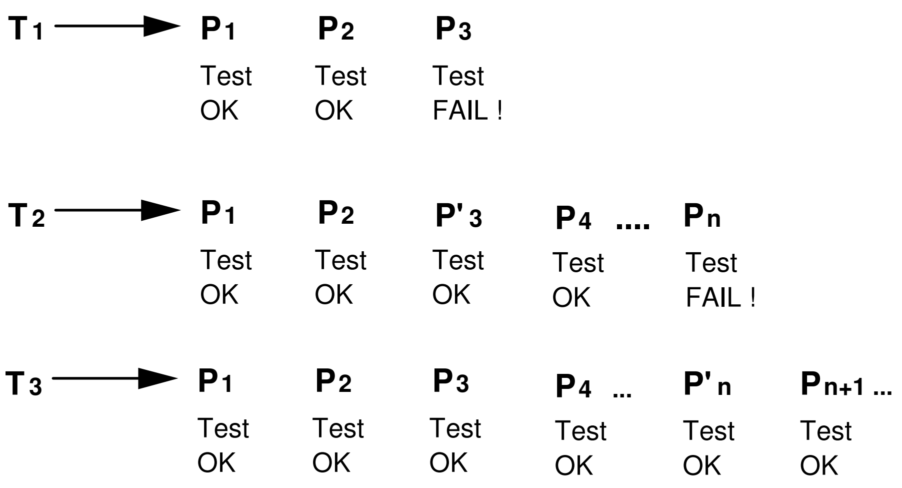
Once upon a time there was a scientist named Fred Bloggs. He made up a theory, call it Theory 1 [fig. 2]. [Remember, using Popper's scientific method, we can't tell how to discover or make up a theory. It was a scientific theory because it was testable and falsifiable.] So Fred Bloggs manipulated this theory so that it made a prediction. Prediction Number One. Then Fred Bloggs went out and tested it. He performed an experiment, he made an observation. He tested his prediction, to find out whether the prediction was true or false. Of course he was hoping that it would be false, because, then he'd really know something. Unfortunately he found that Prediction One was confirmed. What he observed in his experiment confirmed his prediction.

FIGURE 2

Then he manipulated his theory a little bit more and came up with another, different prediction. Not the same old one, like heavy bodies will fall, but a new prediction. He then performed another experiment and unfortunately found that the prediction was also okay. The facts of the experiment supported it. Then he manipulated his theory a little more to make a third new prediction. This time, he found, let's call it a question mark. He performed an experiment, and he observed the results of the experiment. The experiment did not agree with his prediction therefore his theory was falsified. His theory had produced a prediction that was incorrect. Now, what must he do? He must not make excuses, he must not pretend it didn't happen. He must not say, let's do it over again, he must not say let's try something new, let's forget about the result; he must say, my theory is falsified, I must throw my theory away. That's it. No procrastinating, no delay, no double dealing, no excuses, no rhetoric. Throw it away. Now we have really learned something. Theory One was false.

According to Popper, if we're lucky, and in the history of physics and astronomy we have been lucky, around about the time that Theory One is proved to be false, someone else will perhaps dream up a theory, Theory Two, which is 'better' than Theory One. 'Better.' What does better mean? Better means, Theory Two makes exactly the same predictions as theory one did, where Theory One was successful. [Fig. 3] Theory Two makes prediction one, and we know that prediction one was okay. It makes prediction two, and prediction two was okay, but now we come to the crunch. Theory One failed at the third hurdle. Its third prediction was false. Well, Theory Two must explain that. In other words, Theory Two must predict correctly, the outcome of the experiment that falsified Theory 1. It must make a, let's call it, prediction 'three prime', which is going to be the outcome of this experiment. Now Theory Two is better than Theory One. It explains what Theory One explained and it explains the point about which Theory One failed. And presumably Theory Two will go on. It will make prediction four, which will be confirmed, prediction five, which will be confirmed, and then maybe somewhere, it will make prediction n, and prediction n will not be supported by observational and experimental evidence. Prediction "n" will be wrong. And what do we do now? Exactly the same thing. Goodbye, Theory Two and we hope that someone will now think up a better theory, Theory Three. Which will explain everything that Theory Two successfully explained, and explain the point at which Theory Two failed.

FIGURE 3



Perhaps Theory 1 is Aristotle, perhaps Theory 2 is Newton, perhaps Theory 3 is Einstein. We now have 'progress', because the series of confirmed predictions gets longer and longer, and we have revolutions, because these are revolutions, when we went from Theory One to Theory Two we completely rejected Theory One and in a certain sense, the view of things that went along with Theory One. We threw it out and we adopted a different theory. A different perspective. A theoretical revolution. According to Popper, we have now dealt with theory loading, we have understood discovery as a creative act, we have accounted for the existence of revolutions in science, and we have allowed for progress in science. This looks pretty good and many people accept this picture of method. I am now going to suggest, however, that it is completely wrong-headed and unconvincing. For three reasons:

The first reason (which we develop in our follow up course HPSC 2100 on The Scientific Revolution) is that when we look at the great theories, like those of Copernicus, Newton, Einstein or Darwin, we find that at the moment of their very birth each one was faced with apparently crushing falsifying evidence. If scientists really followed Popper's method, each of those theories would have been thrown out the moment it was published or put forward, because there was apparently very strong falsifying evidence in each case. Let me use an example from Copernicanism, but we could also do this with Newton, we could do it with Einstein, and we could do it with Watson, Crick and DNA. Copernicus' theory was published in 1543 and from the stand-point of the belief system of the day, the theory was faced with immediate falsifying evidence.

We are familiar with some of this. At a rough guess, if the earth is spinning, during the time which it takes a piece of chalk to fall to the ground, which is perhaps a second, the earth should spin a couple of hundred metres, three or four hundred feet. Surely, if the earth were spinning, and we dropped a piece of chalk, the earth would spin while the chalk was falling and the chalk would fall far to the west of where I dropped it, because the earth is spinning west to east: crucial experiment! Copernicus' theory seems to predict that things will fall to the west. Did he really? No. But, to his opponents the theory seemed logically to predict that things will fall to the west; and they don't. [In fact, they do a little bit, but not enough to see with the naked eye.] So, many concluded that Copernicus' theory made a false prediction. So what did they do? What should we do?
If Copernicus had been called Popper he would have slit his throat at that point. Or, slit his theory's throat. What did the real Copernicus do in this situation. Did Copernicus behave in the way that Popper said scientists are supposed to behave. (And by the way, there were other similar problems like stellar parallax predicted by Copernicus' theory, but not observed until 300 years later). Copernicus's actual response in this situation was, well, whatever the Polish for "tough" is. Tough luck, too bad. That's the response: I will ignore this problem, something will turn up, and something did turn up 89 years later. Now the question is, whether Popper's method means that we are allowed to wait for 89 years to see whether a falsification is not a falsification.

All of a sudden this method is not looking like a method; it's looking like a fairy tale.

However, something did turn up, and this will lead to the second point. Galileo turned up in 1632, and Galileo said, I have just invented a new theory. It's called the theory of inertia. Now if you believe this theory then you will not be worried by the above experiment. You will understand that this experiment of dropping the chalk does not prove Copernicus wrong. It doesn't necessarily prove he's right, but it certainly doesn't prove that he is wrong. Now what I am going to say is not strictly Newton's inertia of 50 years later, this is Galileo's more rough and ready notion of inertia.

If we have a system of bodies, and no informational input [we are talking in 20th century language], then we inside the system, cannot tell whether that system is moving or not. So imagine we are in a train. There is no friction of the wheels. There is no noise. There is no wind outside. The windows are blacked out. We have no informational contact from outside. We probably wouldn't be able to tell, from inside the train, whether the train is moving or not. [Newton would say, we'd damn well know it was moving if it suddenly stopped or accelerated!]

But leaving that aside, Galileo didn't think of that. We wouldn't really be able to tell from the inside if the train was moving or not, but we would certainly be able to see things moving within the train: people walking up and down, people dropping things, people doing things, whatever. Galileo says, the spinning earth is an inertial system (It's not, according to Newton) and so you see, the atmosphere is moving along with the earth, the building is moving along with the earth, the piece of chalk is moving along with the earth. So when we drop the chalk, the earth doesn't spin underneath the chalk, the chalk keeps spinning with the earth. We are all moving along. We are all in the same system. And of course as we are all in the same boat, as it were, we don't observe any relative sideways westward motion in the piece of chalk. This account does not prove that the earth spins. What it says is, it is possible that this experimental observation is consistent with the earth spinning.

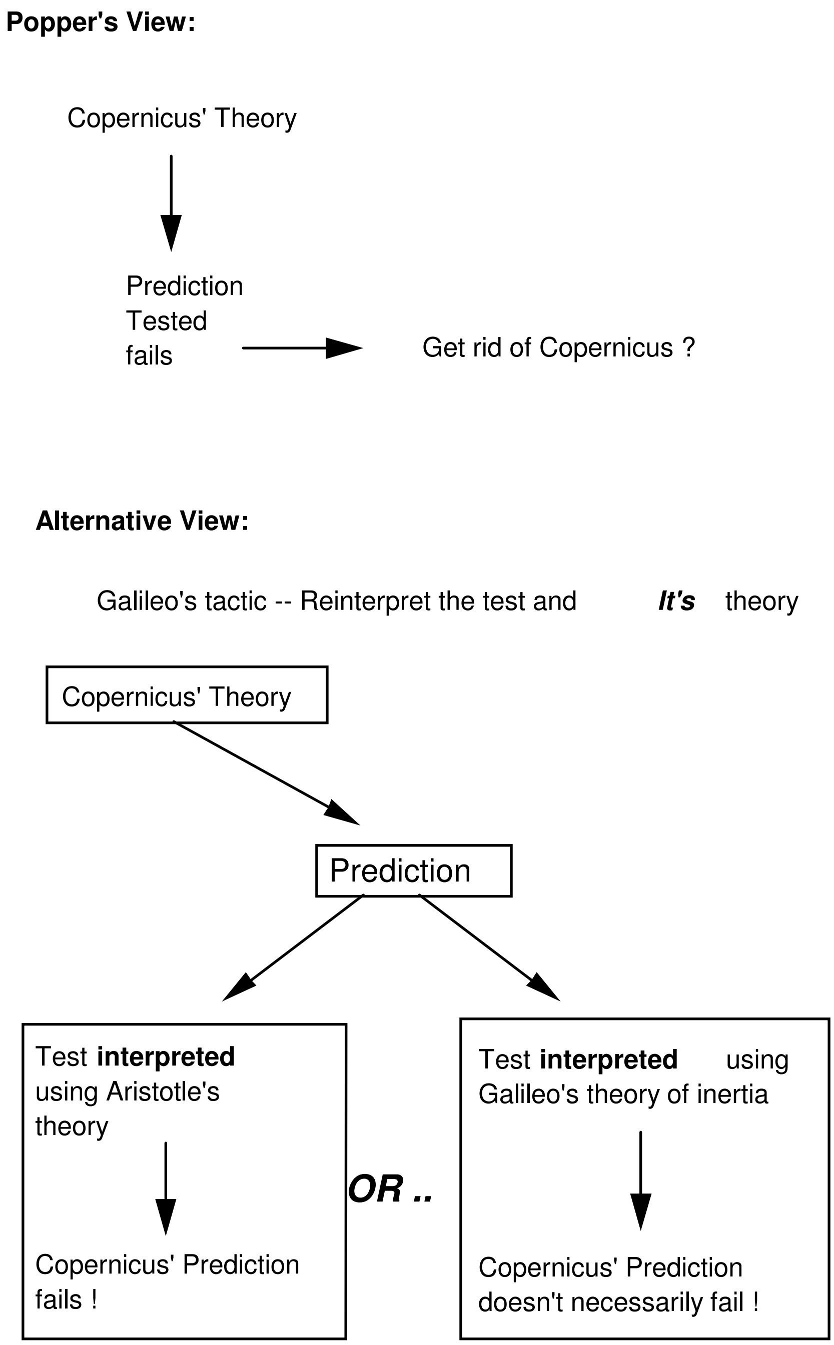
Now, this leads to the second point against Popper. Obviously no test is conclusive, because tests are conducted and interpreted in the light of theories and the theory of a test can be contested. Galileo has just challenged the usual interpretation of this test. [fig. 4]

Galileo has said:

> *I know what you're doing, when you say this proves the earth doesn't spin. You're assuming Aristotle's physics. You're assuming the earth doesn't spin. And that if it did, it would spin, but the chalk wouldn't spin with it. You are interpreting the test your way, according to Aristotle. I, Galileo, have suggested an alternative explanation, an alternative interpretation. Think of this as a test carried out in an inertial system, which might or might not be moving. You'll get the same result in either case. So it could be an inertial system that's moving, and yet we all observe the the chalk falls straight down!*

Galileo has done away with the falsification. He said, wait a minute, that theory isn't falsified by the experiment, because I'll give you another theory for interpreting the experiment. But Popper doesn't allow this. Popper thinks this kind of move is dishonest. You can't do an experiment, see your theory falsified, and then dream up a new theory that will take away the sting of the test. He considers this highly dishonest. Perhaps it is, but this seems in effect the real social, political and intellectual dynamics of science.

FIGURE 4



People are not really going to follow Popper's method. They are going to defend their theories and one of the best ways to defend them is to challenge the basis of an experiment that supposedly threatens your own theory. We see this all the time in environmental disputes, in technical disputes, in medical disputes and in controversies within the scientific community.

Now the final example, this is the third point against Popper, and we have already gone through it in the last chapter on the 'politics of testing' when we explored the key idea that 'test data do not speak for themselves'. Unlike what we learned about the need to always 'negotiate' the meaning of the prediction/data gap, Popper's approach assumes that we do a test and simply arrive at a result. The test speaks to us. We do a test and the test says, "Hello I'm a test. I consist of resultant data and I am telling you that your prediction is wrong, your prediction is false." Or alternatively, "Hello, I'm test data, your prediction is okay." (See Chapter 6, figures 4 & 5)

Think about it, data do not speak for themselves. People speak for data, and the reason people speak for data is when you have a theory, and you make a prediction, and you do a test, and you get data, there is always a gap, a quantitative gap of some form, between the predicted numbers and the data numbers. That's why the data can't speak to you. You have to speak for the gap. You have to come in, as a scientist, and say, I believe the gap is too big enough here, that we can conclude that the prediction is false. Or, I believe that the data are close enough to the prediction. There is no rule or method or model for deciding when a gap is 'so big' that the prediction is 'wrong', or when a gap is 'so small' that the prediction is 'true'.

Now some of you may ask, what about statistical methods? And I will tell you, you always have to make assumptions. You always have to lay down conventions about what's acceptable and what isn't. Just because a whole profession accepts certain standards as constituting 'confirmation', that doesn't mean those standards can't be challenged, or that that means anything in the real world. It's just a set of conventions and conventions are set through a process of negotiation. So, again, Popper misses the point, and that is, every time there is a test, the relevant experimenters, the relevant scientists are going to negotiate and argue with each other about the meaning of the test, especially the size and meaning of the inevitable 'gap'; and honest men and women can differ about the outcome of the test. If they can, there is no method in the simple Popperian sense.

What's Popper telling us in the history and sociology of science today? He's not telling us anything that we need to know. What we really need to know is, how do professional scientists argue about and negotiate what they are going to make out of the outcome of the test. To tell us, "Do a test and if you pass, it's okay, and if you fail, throw away your theory" is to tell us nothing.

Now, scientists might argue with each other in the following way: they might say, I'm a Popperian and Karl Popper says, you must do it this way. But that's just a story, a way of convincing other scientists to accept your reading of the size and meaning of a 'gap'. There are other stories, **and they can hurl them at**

each other as part of this social negotiation and struggle to 'name the meaning of the gap'. That is, Popper's method story can be a rhetorical tool in scientists' negotiations over 'gaps' and results -- but it cannot actually be used as a procedure, or method, to simply arriving at a universally agreed result.

In sum, even Popper's attempt to revamp the method story fails, and that leaves us with the possiblity that science is performed without a method: that is, it has a different sort of dynamics and rhythm of change and growth. In the next chapter we look at the most important 'post-method' account of scientific work and scientific change -- that of Thomas S. Kuhn.