SCEPTICAL SCIENTIST OR BELIEVING BOFFIN

A talk by Peter Budd
22nd November 2011
St. Andrew's Church, Cheadle Hulme

Sceptical Scientist
or
Believing Boffin?

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Sceptical scientist or believing boffin? As well as being a Professor of Polymer Chemistry at the University of Manchester, I am a lay Reader at St. Andrew's Church.
Does this create a conflict?
How does my science relate to my faith?

I shall talk first about science. I then hope to show that faith – a worthwhile faith – has more in common with science than many might think.

SCIENCE

The reason I'm a scientist is that science is fun. I'm a big kid at heart. I like having a really massive chemistry set to play with.

Of course, these days, it's my students who get to play in the lab. And perhaps they don't always find it fun, because there's a lot of frustration in research.

But like many people, I got involved with science because it's fun!

Why is the sky blue?
Is there anything beyond the universe?
How big is the universe?
Is there a God?
What is matter made of?

CURIOSITY

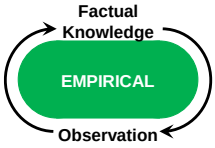
Is there a right way to live?
What is energy?
What makes things grow?
Why do some things go bang?
Where do babies come from?

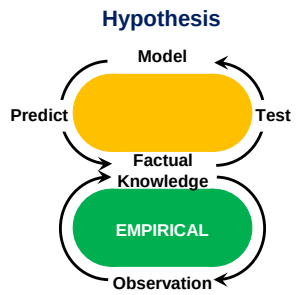
And I have an insatiable curiosity.

Like a kid, there are all sorts of questions I'd like answered.

How do we get answers to our questions?

So how do we get answers to our questions?

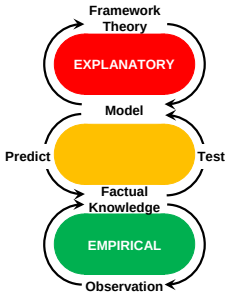
Asking authority **How do we get answers to our questions?**	From an early age, we ask people who should know. We look to authority. "Mummy, Daddy, why is this?...what is that?..."
Asking authority **Thinking** rationality **How do we get answers to our questions?**	Then we realise we can work things out for ourselves. We can think things through; use our rationality.
Asking authority **Thinking** rationality **How do we get answers to our questions?** **Feeling** intuition	But actually, human beings are remarkably irrational. We tend to accept answers based on our feelings. On "gut reaction" or "intuition".
Asking authority **Thinking** rationality **How do we get answers to our questions?** **Feeling** intuition **Looking** observation	And we get answers from what we observe. From looking at the world around us.
	Now science involves all these things, but what distinguishes science from other forms of philosophy – what makes science "science" – is that it's ultimately rooted in OBSERVATION. It has an empirical basis. We build up a body of factual knowledge on the basis of observation. In particular, observation under highly controlled conditions that we call an "experiment".



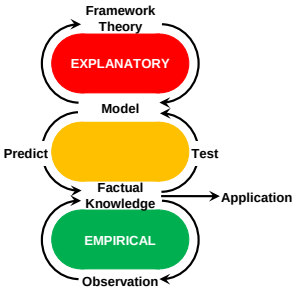
But science isn't just about facts. We want to understand the facts. We want explanations.

So we formulate hypotheses. We construct models, to make predictions we can test.

We try to make our models as quantitative as possible, which means they often have a mathematical form.



If a model consistently proves its worth – if it keeps passing the test – we incorporate it into a wider, explanatory picture of the universe: A framework theory.

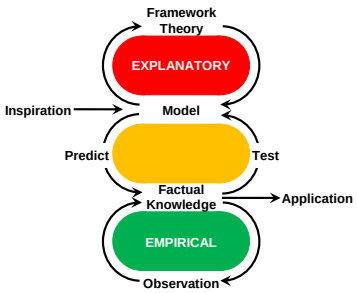


But, however fascinating the theories we come up with, the taxpayer doesn't pay us just to have fun in the lab and to have grand ideas.

The taxpayer pays us, because science is useful. It has application. It helps feed us, clothe us and heal us. It identifies and provides solutions to many of the problems we face.

It has an IMPACT on our lives and the world we live in.

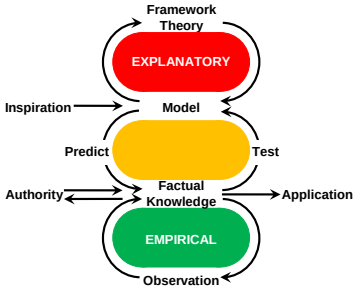
So, here we have a process of observation and explanation that gives rise to application.



But science is always in a state of flux. There's a role for inspiration. Ideas come along that run counter to accepted wisdom.

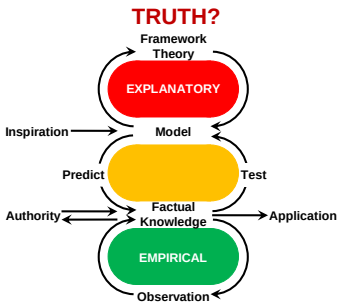
Usually those ideas turn out to be rubbish, but sometimes they are found to have better explanatory power. And so the framework theory is modified, or even replaced; a so-called "paradigm shift".

Observation, explanation, application and inspiration.



But when we start out in science, we don't do every possible experiment ourselves. We learn from teachers, from books, from authority.

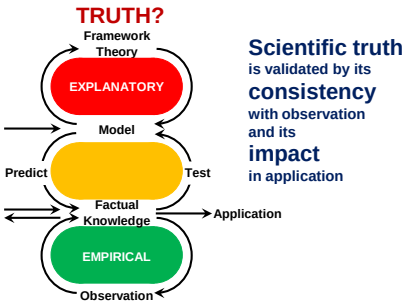
But that authority is ultimately derived from the empirical basis of science.



So here we have a simple model of the scientific process.

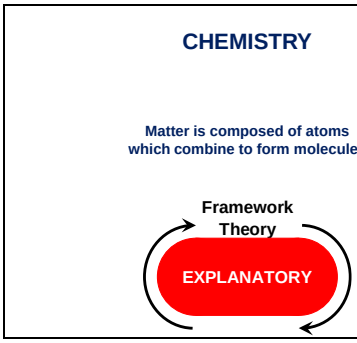
But the question arises: to what extent should the accepted framework theory at any given time be regarded as "truth"?

Well, if the theory works – and keeps on working – we tend to think we're at least close to understanding something "true" about the universe.



Ultimately, scientific truth is validated by its consistency with observation and its impact in application.

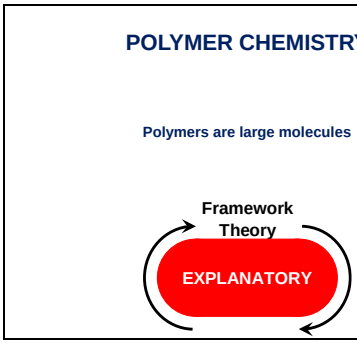
In other words, we accept it because it works and because it's useful.



Let's see how this applies in my own subject area.

There's a key framework theory that runs right through the whole of chemistry. We couldn't imagine chemistry nowadays without it. It's the idea that matter is composed of atoms which combine to form molecules.

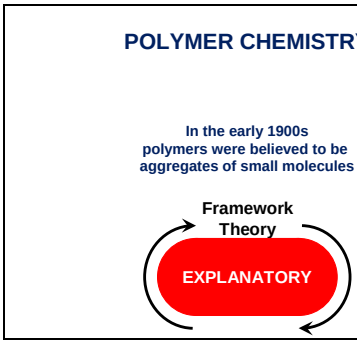
Of course, this hasn't always been the accepted theory. A scientist who spent much of his working life in Manchester – John Dalton – played a key role in the development of modern atomic theory.



My own research has to do with polymers.

Polymers are all around us, from the textiles we wear to the complex molecules that carry our genetic code. What all polymers have in common is that they are very large molecules.

Of course, this hasn't always been the accepted theory.



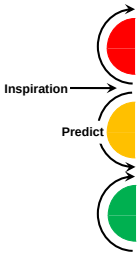
If we go back to the early 1900s,
polymers were believed to be aggregates of small molecules.

Hermann Staudinger
1881-1965

In 1925 Staudinger was told:

Leave the concept of large molecules well alone; organic molecules with a molecular weight above 5000 do not exist.

Quoted in R. Olby, *J. Chem. Edu.*,1970, **47**, 168.



It was Hermann Staudinger who really pushed the idea that polymers were actually large molecules.

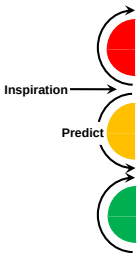
In 1925, he was told categorically:
"Leave the concept of large molecules well alone;
organic molecules with a molecular weight above 5,000 do not exist."

Hermann Staudinger
1881-1965

He responded
(quoting Luther):

"Hier stehe ich, ich kann nicht anders"

(Here I stand, I can do no other)



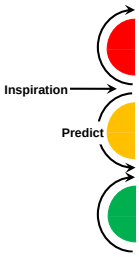
Staudinger's response was to quote Martin Luther:
"Here I stand, I can do no other."

A scientist using language more often associated with faith.

Hermann Staudinger
1881-1965

What convinced Staudinger that polymers were large molecules?

Why did his contemporaries think such large molecules could not exist?



Why was Staudinger convinced that polymers were really big molecules?

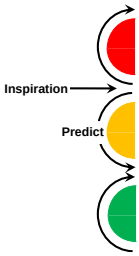
And why were his contemporaries certain he was wrong?

Staudinger's conviction was based on evidence. In 1925 he thought he had enough evidence to make his case, but it was several more years and a good many PhD students' theses before his sceptical colleagues were convinced.

Hermann Staudinger
1881-1965

Staudinger was convinced by the evidence he had.

His contemporaries were misled by assumptions they made.



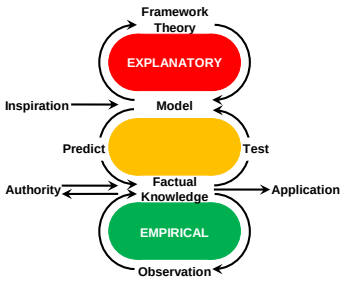
As for his contemporaries, with hindsight we can see they were making assumptions that had no evidential basis.

For example, they thought a molecule couldn't be larger than its crystalline unit cell. Nowadays, we can see there was no good reason to think that. At the time, however, it was difficult to break out of that way of thinking.

Many of you will be familiar with this picture, which can be seen either as a young lady or as an old woman. Some see one; some see the other. Some can easily switch from one image to the other, whilst others never manage to.

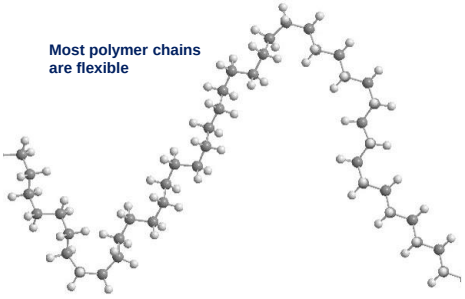
It can be all too easy to get locked into one way of looking at things, and fail to realise there's a different perspective.

Staudinger could see the potential of the young macromolecular hypothesis, whilst his contemporaries were stuck with the old hag of traditional ways of thinking.



I've given you a brief idea of how science works.

But how does this apply to my own research?

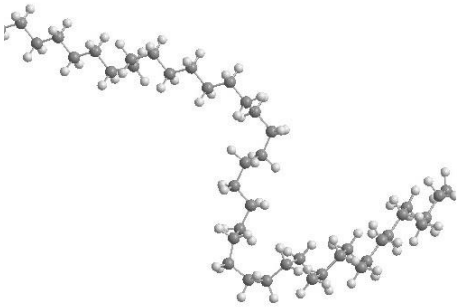


We've seen it was Hermann Staudinger who really pushed the idea of polymers as big molecules, even when everyone else was against the idea.

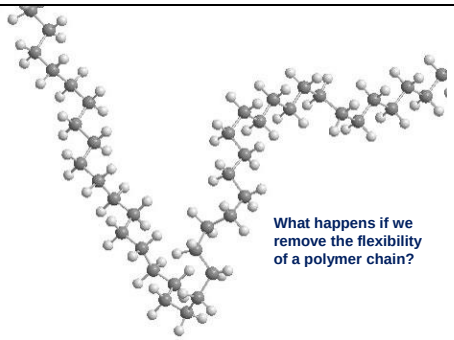
Staudinger was proved right about that. But Staudinger didn't get everything right.

One thing Staudinger got wrong was that he thought polymers were very rigid molecules.

We now know that most polymer chains are flexible, and this gives rise to many important properties.



Given the chance – in solution or in the rubbery state – a polymer chain can wiggle and twist and adopt many different shapes.



A question I have been asking in my research is:
"What happens if we remove the flexibility of a polymer chain?"

Flexible polymer chains can rearrange and in the solid state they to a large extent fill space.

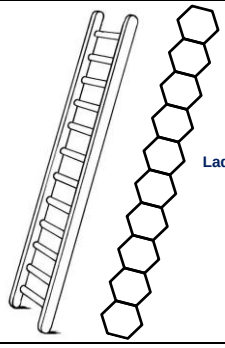
We can make very rigid polymer chains – much as Staudinger imagined them – but they tend to pack even more densely and are very difficult to do anything with.

But if we can make a chain that is both rigid and contorted – more like crispy noodles than spaghetti – it won't be able to fill space efficiently.

Molecular sieve

That sort of polymer should trap bits of space that little molecules can get into. In other words, it should behave as a "molecular sieve", or a "microporous material", where the word "microporous" refers to holes not much bigger than molecules, less than a couple of nanometers in size.

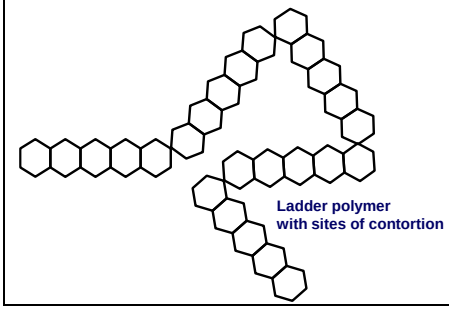
This is the basic idea behind a new type of polymer that we call a "polymer of intrinsic microporosity", or PIM for short.



Ladder polymer

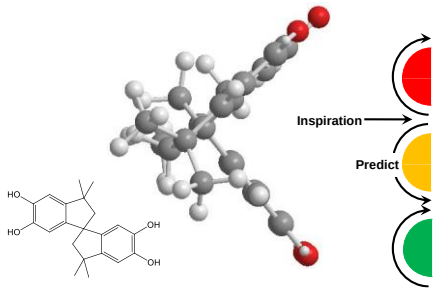
But how do we put this idea into practice?

First we need a polymer backbone that is rigid in the sense that rotations about backbone bonds are prohibited. We do this by constructing the polymer out of ladder sequences.

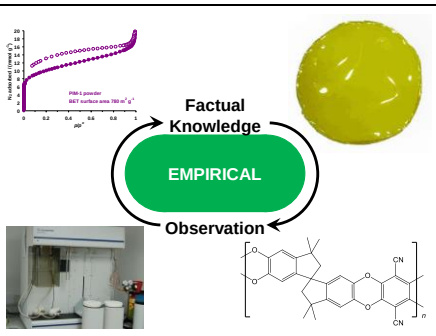


Ladder polymer with sites of contortion

Then we need to introduce sites of contortion. Something to make the chain twist and turn.

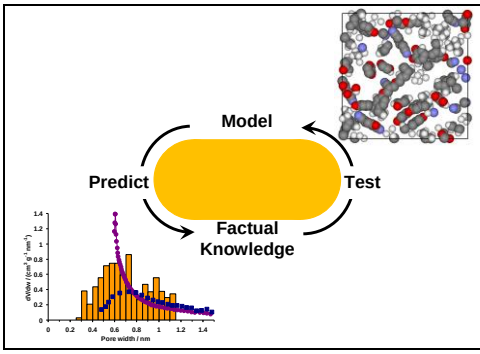


An important bit of inspiration came when my collaborator, Neil McKeown, was leafing through a laboratory catalogue and spotted a molecule with a spiro-centre. He realized this could be used to hold groups at an angle to each other. At the time, we were trying to incorporate certain catalytic groups into a polymer network and make them accessible.



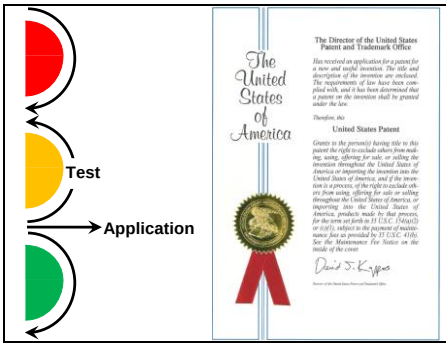
Later, we realised we could make solution-processible polymers based on the same unit, and similar units. That led to a whole family of PIMs, the most important of which we call PIM-1.

Nitrogen adsorption experiments demonstrated that PIM-1 behaves like a microporous material. We went on to form membranes of PIM-1, and showed that they were potentially useful for things like separating alcohol from water, or oxygen from air, or carbon dioxide from a mixture of other gases.



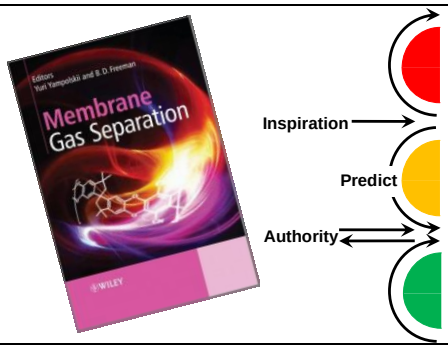
To understand our polymers better, we have been collaborating with many other research groups.

For example, people have been using computer models to test our ideas and to predict the behaviour of PIMs with different structures.

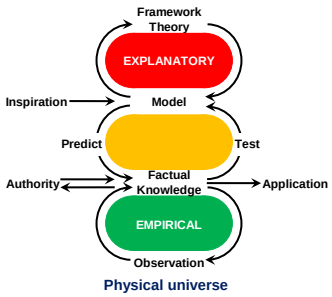


It takes a long time to turn an idea into something useful. We filed a patent application back in 2003, but it was several years before patents were granted.

Through the University's technology transfer company, our intellectual property was licensed to a company that had a product on the market for a number of years.



In the meantime, our polymers have created quite a bit of interest in certain areas.



I've given you a brief idea of how science works.

Science is a wonderful way of finding answers to questions about the universe we live in – the physical universe – and of applying what we learn

Are there questions science cannot answer?

But are there questions science cannot answer?

Is there a RIGHT way to live?	What about questions such as: “Is there a right way to live?” Questions of morality. Science in itself is morally neutral. It can be used in ways most would consider “good” and in ways most would consider “bad”, but it doesn’t tell you what is “good” and “bad”. Science requires certain moral standards of its practitioners – in particular, honesty – but morality is something the scientist brings to the subject, not something that arises from it.

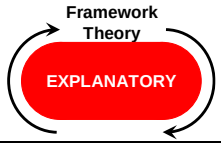
Is there a RIGHT way to live? **Is there anything beyond the physical universe?** **Is there a GOD?**	Then there are questions such as: “Is there anything beyond the physical universe?” And more specifically: “Is there a God?” Of course, if you adopt the philosophy sometimes called “naturalism” or “materialism”, then your assumption is that there is nothing beyond the physical universe, in which case these questions are irrelevant as far as you’re concerned. But that is an assumption. A blind belief.

FAITH	So how does faith relate to all this.

Personal **FAITH**	Now any faith is intensely personal. It’s linked to an individual’s feelings and experiences. And Christian faith, in particular, requires a personal response, because it’s about relationships: our relationship with God and our relationships with each other. So faith can seem subjective. But does that mean it’s purely subjective? Or is there also an objective aspect of faith?

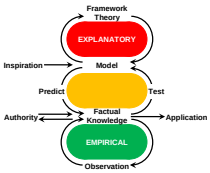
Personal **FAITH** **based on evidence**	In particular, when the claims of faith go beyond the individual to the general – such as the claim there is a God before whom all will answer for their behaviour – then one can expect some kind of objective evidence and not merely personal opinion. I would suggest that a worthwhile faith, as well as being personally meaningful, has an evidential basis.

GOD



Running through many of the main religions is a key framework theory: The idea that there is some kind of God.

GOD



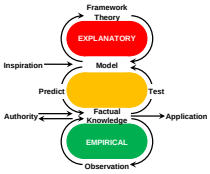
since the creation of the world God's invisible qualities – his eternal power and divine nature – have been clearly seen, being understood from what has been made
Romans 1:20

From the specifically Christian perspective, the Bible says this: "since the creation of the world God's invisible qualities – his eternal power and divine nature – have been clearly seen, being understood from what has been made."

In other words, there's evidence of God in the world around us. Christian faith has an evidential basis.

There are many strands of evidence we could point to. No one strand in itself constitutes proof; it's always possible to think of alternative explanations. But put everything together and I, at least, find the cumulative evidence convincing.

GOD



The existence of the universe
The intelligibility of the universe
The fine-tuning of the universe

We can point to the existence of a Universe which at least appears to have a beginning, or some kind of finite bound. That's easy to understand in terms of a self-existent cause.

We can point to the intelligibility of the Universe; the fact it shows regularity of behaviour, so the scientific method works. That's easy to understand if it's the product of an intelligent mind.

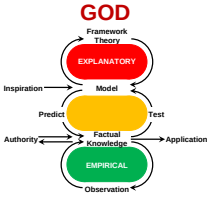
We can point to the fine-tuning of the Universe; the fact that so many parameters are just right for our existence. You can speculate about a multiverse, but even a multiverse doesn't necessarily do away with God.

The facts of the Universe can be taken to point to some sort of external cause, but that is a long way from, for example, the personal God of Christian belief.

It could be a deistic God; a God who winds everything up but has no further interest in us, in which case it doesn't matter whether or not we believe in him, her or it.

Is there evidence for a God who is actually concerned about us and how we behave?

GOD

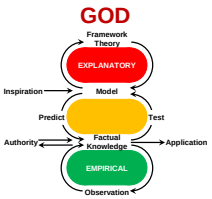


So I find this law at work:
When I want to do good,
evil is right there with me.
Romans 7:21

The bit of the universe we should know most about – the bit we have the most direct experience of – is ourselves and our fellow human beings.

Pretty much everyone has some kind of sense of "right" and "wrong"; a sense that some things are "good" and some things are "bad". But the really curious thing is that nobody manages to do always what they consider "good".

The apostle Paul expressed it like this: "So I find this law at work: When I want to do good, evil is right there with me."



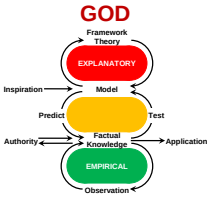
So I find this law at work: When I want to do good, evil is right there with me.
Romans 7:21

The law of human nature
C.S. Lewis

C.S. Lewis called this “the law of human nature”.

The sense of a standard of “goodness” beyond what we can achieve, is just what we would expect if there is something beyond ourselves – a God – who epitomises goodness.

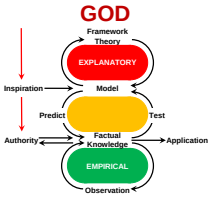
But if we have to answer to that God for our behaviour, we have a problem.



through Christ Jesus the law of the Spirit of life set me free from the law of sin and death
Romans 8:2

The Christian claim is that God is not only concerned about us and how we behave, but that he loves us so much he entered into human history and, in a quite horrifying way, provided a means for us to escape the ultimate consequences of our behaviour.

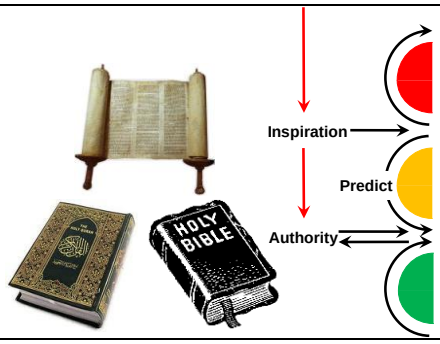
But this goes beyond what we can infer just from what we see in the universe and in ourselves.



We can only know details of that which is beyond the physical universe, if there is information from “beyond”.

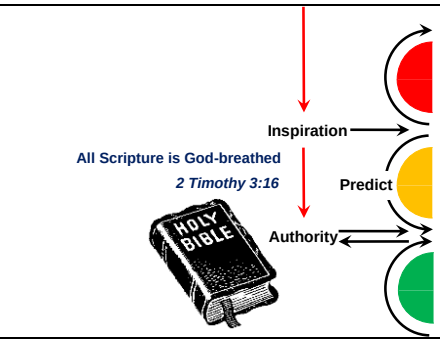
We need information from “beyond” in a form we can examine objectively. Something that has stood the test of time.

A book, perhaps.



There are, of course, many writings which claim to tell about God.

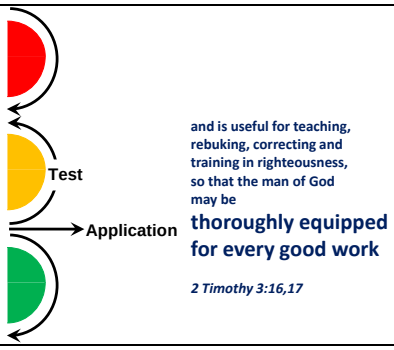
I shan’t attempt a comparison here, but will point to some of the claims in the Christian Bible.



In 2 Timothy 3:16 – talking specifically about the Hebrew Scriptures, our Old Testament – it says: “All Scripture is God-breathed.”

In other words, here we have writings that are inspired by God.

But it doesn’t stop there. It goes on to state the purpose for which Scripture is given:



"and is useful for teaching, rebuking, correcting and training in righteousness, so that the man of God may be thoroughly equipped for every good work."

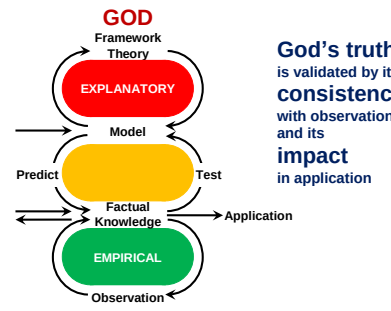
It is meant to be useful. It equips for "good work".

In other words, it should have an IMPACT in people's lives and in the world.

We all have questions about ourselves and the universe we live in.

Authority, rationality, intuition and observation help us to answer questions, and all play their part in both science and faith.

But observation is particularly important as the foundation of science. And observation underlies a faith that is worthwhile.



For me as a scientist, God's truth – like scientific truth – is validated by its consistency with observation and its impact in application.

Faith – a worthwhile faith – has an evidential basis; it is consistent with what we see in the world around us and in our own lives.

And faith – a worthwhile faith – is useful; it changes lives for the better.

For me, science and faith are in perfect harmony.

Sceptical scientist AND believing boffin.