Creating Science

The history and philosophy of knowing – a beginner's journey

1. Scientific knowledge is Created.

What have you to say about the following;

[1]Caloric theory

There is an invisible, self-repelling, and possibly anti-gravity substance that when it is collected together creates the experience of heat, and where it is not creates the experience of cold. Just as normal water can flow from uphill to downhill, this "caloric" flows from hot objects to colder ones, making the hot ones cooler and cool ones warmer. The sun has a lot of caloric, the ice caps very little. This helps to explain why most materials expand under heat – they are absorbing a self-repelling material called caloric. This theory has successfully been used to correct measurements in the speed of sound in air that Isaac Newton's theory could not. Do you believe in caloric?

[2]Miasma theory

Miasma means cloud or haze, and it's clearly apparent that where bad smells linger, people tend to become more often ill. Take sticky sewage water, or a rotting meat – both known causes of illness. Conversely, those who have lots of fresh air tend to stay healthier, such as in the country or outdoors. This theory is based on the century's old understanding of bodily humours; which medicine has used to save countless lives. During the plague doctors would successfully protect themselves from the miasma around victims with masks, the 'beaks' full of very smelly herbs. Miasma theory was successfully used by Florence Nightingale to dramatically cut the number of deaths of those in hospitals under her care, washing bad smells away. Bad smells cause illness by unbalancing bodily fluids such as bile, blood and puss – convince me otherwise!

[3]Fixed earth

The land masses that make up the planet, continents and islands, are essentially fixed – and have been the way they are, with very little change, since the formation of the world. It is *visually obvious* that the 7 continents that make up the bulk of the habitable land have always been more or less that way in every human's lifetime. Yes, they can weather down, and earthquakes occasionally shake things up a bit, but there is no force on earth that can move a *continent*.

[4]Flat earth

Even to the casual observer, the Earth *looks* flat. Could attempts to make it appear spherical simply be a conspiracy? If the Earth was spinning around at 1700 kmph at the equator, why don't we all get flung off? And if it really is spinning around the sun at 100,000 kmph, why aren't people squished down during the day and stretched out at night? Could Antarctica really be an ice wall surrounding the flat world, guarded jealously by NASA conspirators?

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[1] The world's first ice-calorimeter, used in the winter of 1782-83, by Antoine Lavoisier and Pierre-Simon Laplace, used caloric theory. Taken 10 feb 2020 ffrom https://en.wikipedia.org/wiki/Caloric_theory#/media/File:Ice-calorimeter.jpg

[2] • By I. Columbina, ad vivum delineavit. Paulus Fürst Excud〈i〉t. - Internet Archive's copy of Eugen Holländer,Die Karikatur und Satire in der Medizin: Medico-Kunsthistorische Studie von Professor Dr. Eugen Holländer, 2nd edn (Stuttgart:Ferdinand Enke, 1921), fig. 79 (p. 171)., Public Domain, https://commons.wikimedia.org/w/index.php?curid=15677032

[3] By Thomas Kitchin - This file was provided to Wikimedia Commons by Geographicus Rare Antique Maps, a specialist dealer in rare maps and other cartography of the 15th, 16th, 17th, 18th and 19th centuries, as part of a cooperation project., Public Domain, https://commons.wikimedia.org/w/index.php?curid=14675675. Taken 25 feb 2020

[4] English: Physical map of the world in Hellerick triaxial boreal projection. 17 August 2018. Downloaded from Creative Commons Wikipedia 10 feb 2020 from https://en.wikipedia.org/wiki/Modern_flat_Earth_societies#/media/File:Physical_world_map_in_Hellerick_triaxial_boreal_projection_-_shallow.jpg

Science revealed.

In our modern world, everyone *wants* science. Every laundry detergent is 'scientifically proven', and every new claim is 'scientists have found'. Science is heralded as the royal course to truth, and those who do not adhere to its claims are promised poverty, failure, sickness and every other ill we can hoist upon our fellow humanity.

True, in the name of science impossible things have been done – diseases entirely eradicated, the dead brought back to life, and the night turned into day.

But what is science, and why has it been so successful, indeed, the most successful thing in history to help us understand how to understand the natural world?

Well to answer those sorts of questions we could take up an entire library. But, instead, we will have to satisfy ourselves with a single book. Best of luck!

What is science?

One thing all the theories on the preceding page all have in common is that at one time respectable scientists thought that they were true. They used these ideas to help them explain and predict the world and, right up to a certain point and then a little bit beyond – these ideas *worked*. At some point, however, the tide of human opinion turned against these ideas and science was forced to adapt, to change, to grow.

But what it did it take? And what is science anyway?

This is, I believe, an ***extremely important question*** for people to ask[5]. Most important things in society are done with the support of, or in the name of, this thing called 'science'. Trillions are spent, reputations forged and felled, and all seem required to follow the edicts of 'science'. So, what is it? Well in reading this book you are required to find, first and foremost, an answer to that question for yourself.

As for myself; science is a wonderful, incredible, revelatory, emancipating and challenging activity. Science is a quest to create a unified account; a series of 'stories' if you will, about how the universe works and to help us make decisions about how to work ourselves within that universe. Yet science is also a decidedly ***human*** activity, with every strength and folly that that enjoins. Science is a quest to know the world, and doing that inevitably leads to something that goes beyond science – the quest to know *yourself*. Thus, science is an important part of the quest for self that each and every one of us are doing; all the time, everywhere.

Who invented science?

No one knows when science *first* got started, perhaps it began with the very first questions people felt needed answering? But a lot of good ideas that we still use in society today came from the ancient Greeks. They thought about thinking[6], taught about teaching[7], questioned almost everything, and had the very good sense to write a lot of it down. Naturally so many questions resulted in a right mess at times, but it also helped to produce some *amazing* people with *amazing* ideas.

One such person, Aristotle, had so many great ideas that many of them are still around today. Not all of them, of course. But one of the most important of ideas he exemplified was that the world was *knowable*, and that knowledge could be gained by *experiences* through the senses. Yes; this idea lacked the rigour of modern science by a long shot, and it ended up making some outrageous claims that really would have sunk had someone checked the next day. But this idea made a difference, and it came to be known as Natural Philosophy, a branch of that great grandparent of all human knowledge: Philosophy[8].

It took the medieval philosophers, working from Latin, to turn the word "scire" (i.e., "to know") into the word we use for natural philosophy today: "Science". Western European medieval scientists might have made an even bigger mess of many things; trying to reconcile Aristotle's early scientific writings with current religious thought, rather creating their *own* theories and then rigorously testing them for their *own* selves. But we **do** owe them a great deal for what science, technology and society became. But to drift carelessly into the etymology or the history of science is not the main goal of the book, but rather to introduce science as it is today, reveal its powers and limitations, and to make suggestions on how science may progress with us into the future.

Is science True?

Entire libraries are devoted to the pursuit of even a mere *definition* truth. I define truth herein as that which continues to be an accurate description of reality despite time or the actions of the observer. This is known as a positivist definition, and it is generally the position most practicing scientists take[9].

This definition of truth is sometimes defined as capital T truth; the objective, absolute truth. Another category of truth is small t truth, the truths that are relative and deeply personal. Which god you worship, who you choose to love,

[5] AKA 'the demarcation problem', or 'what is science, and what is not.'

[6] Called 'metacognition'

[7] Called 'teaching'. "Metateaching" just never caught on ☹

[8] Science began as a branch of philosophy called 'natural philosophy'. The introduction of the scientific method with its emphasis on experiment and evidence-based knowledge (as opposed to just logical analysis) peaking in the 1950's, and resulted in the distinguishing of science from other forms of philosophical inquiry. Science is, however, still properly considered a branch of philosophy. We come back to this point multiple times in our journey.

[9] Harding and Hare, 2002.

and the 'best movie of all time', are true too. Science can comment on these deeply held personal truths, but it does not try to make them absolute, objective, always True truths.

Science *quests* for Truth. But if you embrace post-modernist thought, or simply open mindedness, this book will argue that whether or not science actually *arrives* at Truth is a philosophical question, not a strictly scientific one. Oh, science can inform such a question; indeed, it must. But science cannot answer the question, 'Is science True,' and we will discuss that in greater detail much later. Because it's going to take a while to get there, so I'd better set a few definitions straight first.

Definitions

Arguably, philosophers worry waaay to much about the definitions of words during their discussions. Yet, before we can go any further, we as people asking a philosophical question still need to get onto the same page regarding what we're talking about.

1. Theories

I define theories as **testable explanations** of *why* things happen. They are 'stories' of what unseen underlying processes are occurring that result in the things we do see[i]. (A theory is NOT a guess, at best, that's an hypothesis.)

Theories are what science ***makes***. They are inextricable aspects of what it means to create scientific knowledge. Any national curricular that does not embrace and celebrate theory testing is not teaching scientific thought, they are teaching the memorisation of scientific ideas using entertaining demonstrations and activities.

To become scientists, we have to create, test, and challenge the theories of others, and our own!

Figure 1 See, this is funny because, in science, it's ALL theories

2. Hypothesis

There are more than three definitions of the word 'hypothesis' in science, and that confuses everyone. Fact is, as a word it's not needed at all. Trial guesses at an explanation can be 'tentative theories', and speculations at underlying relationships could easily be 'tentative laws'.

The third, and most illegal, use of the word is as students are taught to use the word to forecast the results of an activity or experiment. The correct scientific term for guessing what will happen is called a PREDICTION and if I ever catch you using the word hypothesis to mean prediction, there will be unspeakable repercussions!

I like to think of hypothesis as 'little explanations', like theories in that they explain things, but not much. They are often brief or tentative explanations, often based on a few or limited observations. Some[ii] would argue that hypothesis that survive initial testing will never chrysalis into fully fledged theories, but hypothesis may help to inform such theories. This seems to be splitting hairs to me, but to each philosopher their own.

A few examples to help you discern a theory from an hypothesis: You try to open your window, and it doesn't open. Is it stuck? Has the little stick fallen down to stop it sliding open? These are <u>hypothesis</u> – based on a few observations and requiring only a minor test. But your underlying <u>theory</u> is in regards your explanation of how your window works – is it sliding, or does it swing outwards? What benefits are there to opening a window that motivated this quest in the first place? These latter two questions are answered by your 'theory of windows'. If you tried to slide a swinging window, you would expect to either fail or break your window. Theories of how the universe works *really matter*, and we are building and developing our theories *all the time.*

Yet this one word 'hypothesis' causes more confusion between students, teachers and philosophers in science than any other. Finding it in a school science text book is like talking to Humpty Dumpty in a Lewis Carroll[iii] novel; ' "When I use a word," Humpty Dumpty said, in rather a scornful tone, "it means just what I choose it to mean—neither more nor less." '.

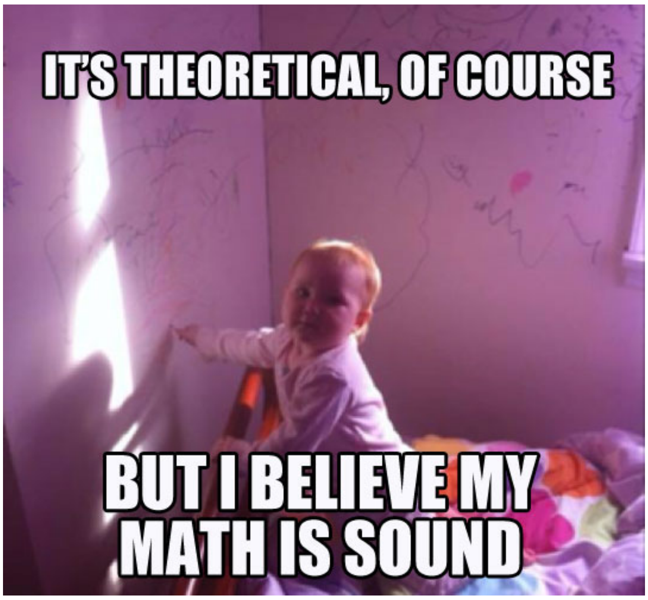

Figure 2 Classical misuse of the word 'theoretical', but we shall allow it.

I see great sense in McComas (1998) recommendation: "The term hypothesis has at least three definitions, and for that reason, should be abandoned and replaced."

3. Law

A law is *a statement of a relationship or pattern* in nature, usually expressed mathematically, while a theory is the *explanation* for that relationship[iv]. For example, Boyle's law tells us that if you make a gas hotter, it will gain pressure and thus take up more space. Boyle's law does **not** say *why* this is so, however. For that, you will need to look to the kinetic theory of heat. Of course, some laws are so intrinsically tied up with their underlying theory that scientists and the media conflate the two, see the 'laws of quantum dynamics' for example.

Note also that scientific laws are *not* laws in the sense that they are timeless and True[10]. Laws, in science, are still only part of our explanations of how the universe works. Contrary to many teacher and student expectations[v], theories don't become laws if they pass the test; laws are subject to change and debate as much as any theory[vi]. For example, Newton's laws of motion were found to only be a subset of more complex laws explained by Einstein. Will Einstein's laws one day prove to not be enough either? We'll need to keep an open mind. Another example may be the development of the gas laws earlier, each adding a contribution till we ended up with a 'universal[11] gas law' – PV=nRT. Laws are up for change, just like any scientific idea![12] – and you know that's True because a University said so.

(But I'm still upset about the use of that word 'universal'…)

Which may be why others are now calling it the Ideal gas law. Because words matter!!

Therefore: Every explanation in science, always, is up for testing and revision. *'True' theories do not become scientific laws!!!* With science, **it's all theories**.

4. Facts

We assume here that a fact is a unit of information. Whether it is true or not is not the question here. My shirt is blue, copper conducts electricity under standard conditions, time slows down the closer one gets to black holes. School science, in effect, tests only students' ability to remember scientific facts, and to a lesser extent their skills at generating such facts in the future. Yet it is a fact that scientific facts change over time as more knowledge accumulates and science gets 'better' at what it does. As noted by the famous quote; "I hate to think of how many things I made students memorise that are no longer considered as true." – or something, I can't find the name.

Facts need not be true to be believed, but that they are believed to be true by most practicing scientists seems necessary to allow them to work in their field without constantly self-doubting. Scientific facts can change for many reasons, not the least of which is that they are found to be incomplete, inaccurate, or simply wrong.

5. Variables

Variables are considered qualitatively different values that can express a difference within themselves, and they receive a proper looking over in the chapter on experimentation. Just for now, they are things we use to describe something. They include things like height, speed, colour, distance, and many, many more. They can be defined overly simply as the *'things that change'*, and inevitably, they affect other things along the way. How fast you can run can depend on how tall you are. Your chance for being pregnant can depend on your gender. Variables change, and they affect other things along the way. Not that height or gender are particularly easy things to change personally, but when looked at over the entire population, it can be seen that there are certain descriptions that do not hold for the entire population. Among humans, there are many different heights, and a fascinating number of expressions of gender.

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[10] Or even that they were made to be broken!

[11] Stupid, stupid choice of word… we have NOT tested every gas under every condition in the Universe!

[12] "Laws are, just like theories, subject to revision. This can happen when more accurate pattern of behavior is observed. Some examples of those are:

1. Ptolemy's law of refraction was replaced by Snell's law.
2. Catriona Reynolds overturned Darcy's law in 2017 (see article or presentation).

For more info watch the video 'Laws of Nature' by Tony Reed and also read the Livescience article 'What Is a Law in Science' which in chapter 'Do laws change' states:

Just because an idea becomes a law, doesn't mean that it can't be changed through scientific research in the future. The use of the word "law" by laymen and scientists differ. When most people talk about a law, they mean something that is absolute. A scientific law is much more flexible. It can have exceptions, be proven wrong or evolve over time, according to the University of California." https://www.quora.com/What-is-a-scientific-law-that-has-been-changed

6. *Truth*

At what point, however, do we really know when our theories are, for want of a better word, 'right'?

Again, that is not a question science can answer, only inform. It is a philosophical question. Many scientists, notably the Realists, like to think their theories are right once they have been rigorously tested. They can sometimes hold on to the theories they defend very devotedly. Almost fanatically, tying their esteem and employability to one particular idea.

Some Realists can take the position that what they believe is truly true until a more true idea comes along. This is the 'open minded realism' that Bhaska speaks of[13]. Again, the goal here is not to convince you, but rather to introduce you some of the most powerful ideas humanity has ever had.

Opposed to Realists might be a group known as the Relativists, who hold that all knowledge is a product of its creators, cultures, their standards and their beliefs. Thus, knowledge is not absolute, but is created relative to its creators. Indeed, the concept of such objective Truth can be seen as nonsensical. As noted in the Stanford Encyclopedia of Philosophy "Defenders see it as a harbinger of tolerance and the only ethical and epistemic stance worthy of the open-minded and tolerant."[vii]

Such a tiny introduction to venerable, deeply held and community-defining philosophies cannot hope to do them justice, but here they are. Nor can we experience the subtlety of the wildly artificial juxtaposition of two great ideas, but this is an introduction after all. Both have so much to add even to begin to understand science in modern society! The interested reader is encouraged to explore each further; for what they are, and what they aren't.

Yet we will return to these ideas again and again as we try to answer the question, 'What is science'? So, for now, let us start with something… simpler;

How do you do science?

So how does one ***do*** science, today? Do you think that *doing* science will give you a better understanding than a thousand books *about* science? How can we know something that hasn't been experienced by us? Let me propose that scientific knowledge, put as simply as I can, grows thus:

1. People have **questions** about the universe.
2. They try to answer those questions. Their answers are called **theories**. A theory is a testable explanation, a 'story', of how the universe works.
3. They test those theories with **experiments**.

[13] Cite.

Figure 3 Can penguins science?

Every fact or theory in science has come about because someone had a question, and they answered it, and they tested their answers. That's an oversimplification, but it shows that you, too, can (and must) use scientific thinking every day. But, also, that scientific knowledge is *created*, and in a certain sense all students of science must learn how to create and recreate that knowledge for themselves.

In school I had a familiar experience with science: To me it involved memorising the facts and ideas of others and occasionally getting to participate in generally interesting activities that illustrated those ideas (called 'experiments'). I had no real idea how scientists came up with all this information, maybe they were just more cleverer than me?

It was many years later that a slow realisation dawned on me that *people* had created that information. *Someone* had to ***create*** that information. Science isn't reading a book about how the world works, its realising that ***we wrote that book***, and that book is as much subject to every human frailty and foible as every other human activity[viii]. Science, this book herein contends, is created by people. It has every strength and fragility every combined work of humanity has ever had. It is filled with every tragedy, travesty, and triumph of mankind. It is one of our greatest works, and it far from complete: Science is always changing.

Scientific knowledge *must* change as people ask more powerful *questions*, come up with more effective *theories*, or find new ways to *experiment* on their ideas. Everyone can do that one way or another. Even the average teacher and the average class can actually add to what science knows as they make and test ideas for themselves. But the entire history of science is filled with dead ideas we no longer hold as scientific – autogenesis, caloric, and flat earth to name a few. Where did those ideas go? And what can we learn from what those ideas became?

Philosophical ramifications in education

We used to say that scientists "discovered" their ideas. This seems to imply that the True and accurate explanation of how the world works was already there, waiting to be found. Postmodernism and other ideas have challenged this belief, suggesting instead that scientific ideas are 'created' just as much as any idea we have. Isaac newton, therefore, didn't discover gravity (it could be said that even cats know about gravity), but what he did do is *create* a complex idea that could explain not only why apples fall, but why the moon stays in orbit, and he called it 'the law of universal gravitation'.

One educational implication from this philosophical shift is known as constructivism – the idea that students construct understanding for themselves. Thus, no longer are scientific ideas distilled truth waiting to be poured into the heads of little learners. Scientific ideas are challenging concepts that students must encounter and then *re-create within themselves*. For example, creating an understanding very similar to the ideas Newton had when he was explaining his idea called 'gravity'. Students don't rediscover the idea called gravity; they recreate it.

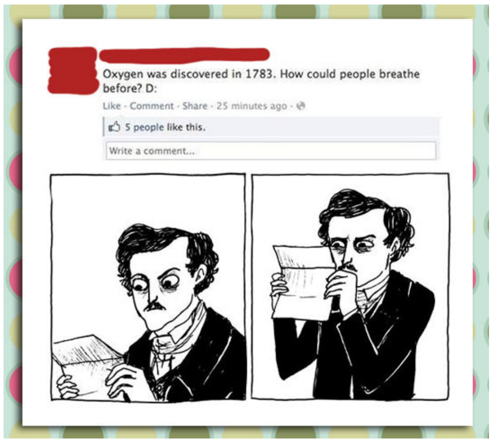


Figure 4 Breathing before oxygen

Since students must recreate rather than rediscover, it means a whole different approach may be taken to teaching and learning science. Students aren't 'wrong' if they don't get it. They are just struggling to be convinced that the new way of knowing is a powerful idea for them to use when trying to make sense of their universe. Usually, students just ditch ideas they don't understand[14]. But scientific research shows that students who persist in understanding do well in schools, more than even clever or rich kids[15].

Teaching now revolves around trying to help students to become convinced of a scientific description. It's no longer about illustrating an idea with an engaging activity, it is, ideally, about respecting an individual's right to learning and thinking, about understanding where they are coming from and how they construct ideas for themselves. It is about exposing them to powerful ideas, and supporting those ideas with meaningful experiences that can help students to recreate those great ideas of modern science within themselves.

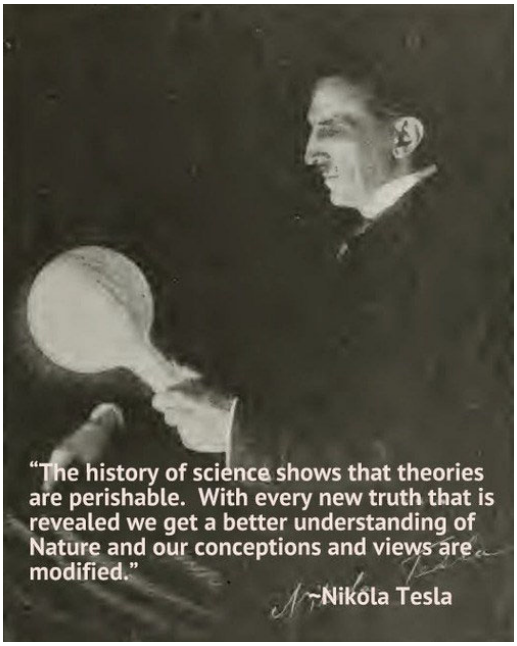


Figure 5 Theories are perishable

[14] citation

[15] citation

Is that all there is to it?

No. Becoming a creator of knowledge in society means we'd want to do our very best. Scientists employ all sorts of tricks to make their created knowledge the rigorous and most effective yet: repeated trials, accurate measurements, fair testing, peer review, comparison with other ideas. Then this knowledge is often put right out into public debate so that it can be tested to the highest possible standards available.

One powerful way to see the creation of scientific knowledge is to treat science like a debate, or an *argument*. Famous scientists all through history have had to engage in such debates to convince the rest of the world that their theory is the most powerful. They used evidence, they created tests others could try, they found ways to show their theory explained more than their competitors. And, yes, sometimes things got a little passionate, treacherous, and even devious in the attempt to win out. Most ***science*** debates, however, are far more easily won; as evidence and logic stack towards one particular theory or another. Famous debates include Germ theory v's spontaneous generation, Lamarkism v's Evolution, and the forces that explained tectonic plate theory.

But then again, once in an often, a completely logical and well supported theory will **upset someone**. It might be that the individual has built their life and career, and income, on the public acceptance of a certain line of reasoning. It might be that entire social organisations feel they rely on people thinking a certain way to validate their existence. How such conflicts have been, are, and may yet be resolved in society is a vital question we need to ask ourselves, for blood has been spilt and lives overturned in the real and imagined battles between science and other ways of thinking. When things turn personal like this, every mechanism of persuasion can be employed – for science is, after all, a very human endeavour.

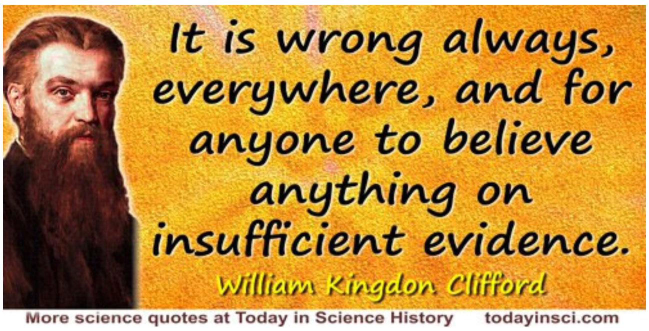
How, then, do we rise above income and ego to develop the best science possible? I submit that there are three standards we ought to strive for;

The Golden standard – Evidence

The **golden standard** of scientific knowledge is, 'Has it been experimented on, and has it passed those tests?' Admittedly, being humans, it's never as clear and polite as that! But as creating the best science goes, nature itself (or, rather, our interpretation of nature) is – in an ideal situation – the final arbiter of 'great' science.

Science is much more than a body of knowledge. It is a way of thinking. This is central to its success. Science invites us to let the facts in, even when they don't conform to our preconceptions. It counsels us to carry alternative hypotheses in our heads and see which ones best match the facts. It urges on us a fine balance between no-holds-barred openness to new ideas, however heretical, and the most rigorous skeptical scrutiny of everything — new ideas and established wisdom. We need wide appreciation of this kind of thinking. It works. It's an essential tool for a democracy in an age of change. Our task is not just to train more scientists but also to deepen public understanding of science.

Carl Sagan, in "Why We Need To Understand Science" in The Skeptical Inquirer Vol. 14, Issue 3, (Spring 1990)



Noted; scientists themselves will battle intensely at and times bitterly for pre-eminence amongst themselves, even against even sound logic and compelling evidence. And, generally, it is appreciated if the uneducated and unscientific keep, for the most part, out of such debates. What, therefore, helps to resolve such debates that cannot be solved by direct reference to evidence?

The Silver Standard - Consensus

Therefore, the **silver standard** against which all new science must be measured is simply this – do most of the experts in a given field rely on that theory to make sense of their work. That is, do they agree the theory is, for want of a better word, true? Or, at least, *true enough to be useful*. Or, at least, least; sufficiently accurate to be worthy of their attention. This process of 'general agreement' is called **consensus**, and it is the most hotly contested area of non-scientists[16].

One vital aspect of attaining consensus of which I was blissfully unaware in my own youth is that of the peer review process. Then I grew up. For myself, I found that getting a doctorate wasn't so much difficult, as it was long. And it's one of the only assignments you'll ever do where the only mark you are allowed to get is an A or A+. So, the thesis supervisors make suggested edits and you write and rewrite drafts more than 20 times until your thesis is up to that standard. It was, for me, deeply enlightening. I'd never had to meet *national* standard before. But who marks such an assignment? At thesis level there is no all-embracing, dehumanising, standard. You must simply pass the judgement of at least two other doctoral level professionals currently working in the industry. If your now new peers think you did a good job at creating new knowledge, you pass, or you pass with honours.

The same goes for writing professional papers that try to direct or reveal information and unique ways of thinking to your profession. Again, the silver standard is if it passes the judgement of your professional peers working in the field. This peer review process is justifiably honoured – it's very easy to publish anything you like, and a lot harder to get it published in a peer reviewed journal. But, for the efforts and even with its glaring limitations, the peer review process not only helps to weed out poor or aberrant thinking; I can tell you from personal experience that it strengthens and helps to clarify the good ones as well.

Figure 6 ... after peer review

The Bronze Standard – grounded/fit

I feel a final **bronze standard** is owed a mention here – does the scientific knowledge that has been created 'fit' with what the current scientific field already assumes is accurate. This is deal with more in later sections, however, perhaps an example will help. Homeopathy is not currently accepted as mainstream science - not because it lacks evidence, and not because it does not have adherents (at times, devoted adherents), but because the idea that diluting toxins to the point of non-existence does not fit with the current scientific narrative that chemicals must be present to have an effect. This is not to say, of course, that homeopathy does work, not that it does not have *some* scientific basis of which we are as yet unaware, though most mainstream scientists stop at 'placebo effect'. But to be brief in writing - to be accepted, new theories must 'fit' with the current scientific narrative of how the world works.

My example from acupuncture serves here as well, though science may yet grow to an understanding that makes acupuncture not only explainable, but fundable by reputed medical bodies. What sort of revelation would that take? An understanding of meridian's, aura's, perhaps even the human spirit?

Science isn't finished, and we need to keep asking questions that help take our knowledge beyond what is currently known, and accepted as true. But, having said, it will not help to outright ignore evidence or the opinion of the very wise who have spent lifetimes studying this because it is not convenient to us personally. But that sort of … humility… is a very human quality.

Here is an unpublishable image that ChatGPT tried to make of the three preceding paragraphs, 12th Nov 2023

[16] "With respect to science, the assumption behind consensus is that science is a source of authority and that authority increases with the number of scientists. Of course, science is not primarily a source of authority. Rather, it is a particularly effective approach to inquiry and analysis. Scepticism is essential to science; consensus is foreign."

Richard S. Lindzen, in "Climate Alarm: Where Does it Come From?" (1 December 2004), a lecture presented to the Marshall Institute. – I don't necessarily agree with this, but dang it's a great point! Perhaps it is simply an acknowledgement that consensus is a more personal and political process, and not an empirical one.

Bodies of scientific knowledge

Now let me treat you to a few more ideas that are beautiful and helpful in experiencing and doing 'science'.

Core science

The notion of core and frontier science is helpful here, developed by Stephen Cole (1992). Core science has generally achieved consensus. It is well established; it is well tested. It fits within the body of respected scientific understanding. It is rarely contested, and it rarely changes. When it is successfully contested it tends to create a major upheaval, like when Copernicus challenged ideas to a heliocentric universe, or when Einstein finally related gravity to relativity.

A point to note here, Cole noticed that core science tends not to get reported in the media. It may be the heart of science, but it is a boring, steady one, beating along faithfully and constantly without much notice, thought, or thanks. Likewise, the mainstream of what happens in 'science' every day just travels along, steady and dependable – microbiologists using pipettes while wearing lab coats, psychologists telling clients about brain changes due to trauma, or botanists trying to avoid personal bias so they throw large quadrats over their shoulders rather than risk looking directly at the field in question. You know, just normal, run of the mill, science.

Frontier science

On the other hand, as you are well aware, not all science fits the descriptions of being established and well tested. Some science is new, and not very well tested, the debates are long and passionate, and it's not always clear how the new theories will fit in the older science.

The reason humanity built the CERN at a cost to the Europeans of 4 billion is to help answer questions about the fundamental makeup of the universe which can only be answered by simulating the situation as it may have occurred at the very beginning. This has never been attempted before on earth. It is the very frontiers of science.

As Cole noted, frontier science is very, very exciting, and thus it *does* get reported in the media, frequently. This, of course, can have the effect of making science and scientists look undecided, confused, underfunded and truly not deserving of such respect as they currently enjoy.

But that is the nature of *frontier* science, not the *entirely* of science. And, obviously, if we stop funding frontier science, we stop science, and may end up in a situation like the dark ages, where questions were not being asked that led to the creation of new, challenging, theories just ready to be tested, debated, and grounded into the body of knowledge that we call 'science'.

The Scrap Heap

In exploring the categories above, Bridgestock[ix] adds another – the scientific scrap heap. This is where old theories go that are generally considered now untrue. All the examples in the introduction fit in such a place, but as we will see, some knowledge has use even after it has been discarded by all thinking minds.

But lets get more into late later on!

The media – society and science

The media make a mint off conflict. So even if science has achieved consensus regarding a given scientific topic, it is in the media's financial best interests to make it look like there's still a big debate.

Frontier science is often interesting, debated, and new. For this reason, it makes much better news than core science, which is often complex, counterintuitive, and boring.

This can leave the public with the impression that NO science is established, trustworthy, or reliable. This is ***simply not the case;*** otherwise, mobile phones would not work, we would never get scientists to Mars, and we would probably still face a 50% mortality rate of newborn infants if not for the body of scientific knowledge that may be considered at its core.

Science works, but when we say 'science works', we're usually talking Core science, or the scientific method. Frontier science is up for debate, and benefits greatly from it. Core science should only go up for debate if there is a really, *really* compelling **scientific** reason for it. Say, for instance; we need to know why machines get hot enough to melt simply when their parts rub together, or we need to know why people can get sick even when we can't smell any reason why. Core scientific ideas *do* change, but not often, and when they do, it's *big* news!

'At the heart of science is an essential balance between two seemingly contradictory attitudes – an openness to new ideas, no matter how bizarre or counterintuitive, and the most ruthlessly skeptical scrutiny of all ideas, old and new. This is how deep truths are winnowed from deep nonsense.

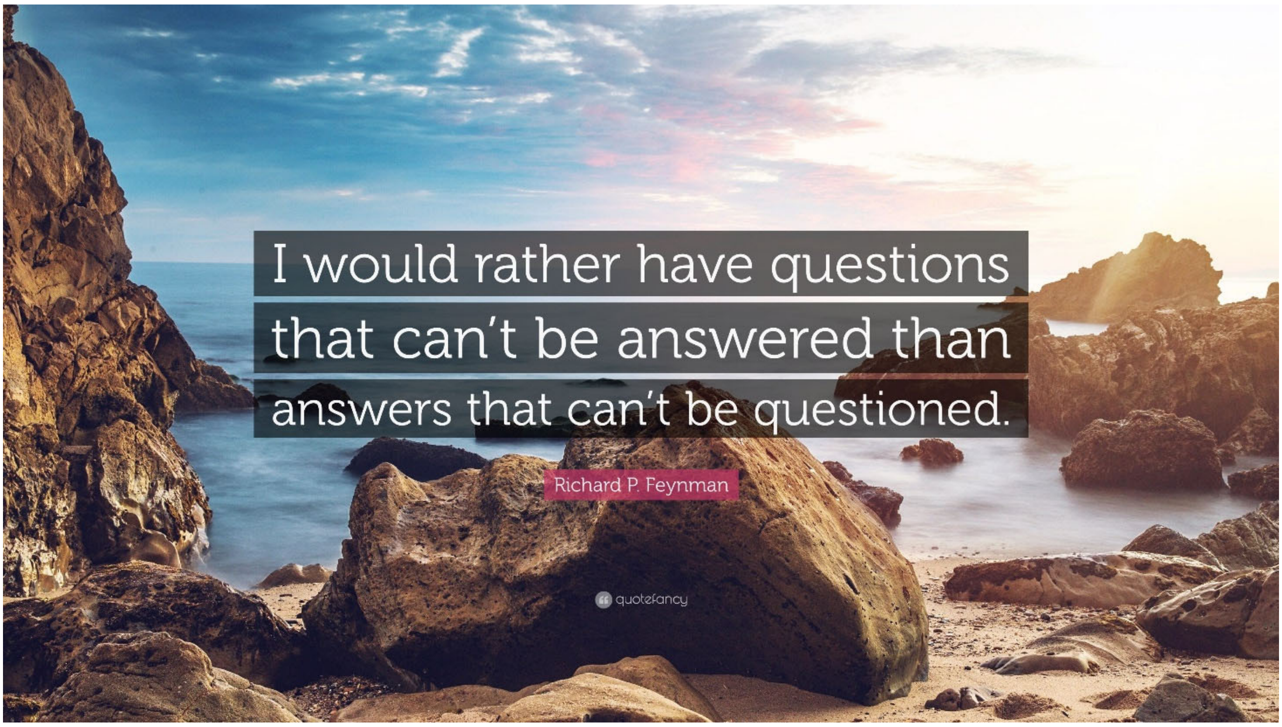
Carl Sagan, The Demon-Haunted World (1995)

Obsoleted theories

- Caloric theory – some theories do such a good job, even for scientists, that it takes a long time for them to go away. Caloric theory is a good example, used in some textbooks even till the end of the 1900's. The only genuine competitor was the mechanical model of heat championed by Baron Kelvin, who pointed out that a cannon became *hotter* when it was drilled out, not *colder* as the removal of material for the caloric to hide in might assume. The final experiment was carefully designed and controlled – rubbing two ice cubes together in a fridge. If the caloric theory held, they should stay frozen, but if motion made heat than the ice would melt. Can you guess what the experiment concluded? Find out more about experiments in chapter 5.
- Miasma theory – theories take time to change. Sometimes it's not the scientists that have to be convinced, but the politicians and public. Miasma theory was replaced by germ theory in the 18th century, a key turning point being the 1854 Broad Street cholera outbreak in London, where people got sick and even died *without* a very bad smell apparent. But until Robert Koch in 1876 definitively showed that the bacterium *Bacillus anthracis* caused anthrax that the theory became generally accepted. The human side of science is discussed more in chapter 8.
- Tectonics? Scientists early last century began to wonder if the continents looked like they could fit together into once piece because, originally, they did. Current credit goes to weather scientist Alfred Wergener for sciencfying the idea and then sticking with it, despite at times bitter opposition. Nowadays the theory of plate tectonics is core, everyday science – the idea that the apparently fixed and unmoving continents are really sliding around on giant plates like the cracks on the eggshell of planet earth. This theory can also explain earthquakes, volcanoes, historically 'upside down' fossil records, and much more. But it doesn't work unless you go beyond what you can see, using your imagination to view a world beyond your immediate senses. Science requires us to use our imaginations, see chapter 3, but also every other chapter.
- Flat earth – conspiracy theories are not scientific because they are, at their heart; untestable. Any evidence *for* is clutched to, and any evidence *against* is passed off as part of the conspiracy. For this reason, philosophers invented such ideas as Falsification – the idea that science cannot prove things true, only false. You can learn about that in Chapter 4. Would it even convince diehard flat Earthers the world is a ball even if they take a trip up to space?

Conclusion

So now we embark, dear reader, on one of the most interesting human journeys of all time: the journey of the creation of knowledge through science. Like the scenes of a famous play that explores the human condition, the journey of science has it all: There will be moments of supernal elation and gut-wrenching disappointment, unmitigated boredom and unyielding pain. Every story of every scientist is a story worth telling. Join along, and you may just get to know your own inner scientist a little better as well.



Rules for reading my book

I did not write this book to be a definitive philosophical treatise on the history and philosophy of science. I wrote it because it is FUN. It is merely an introduction, and I wrote it to appeal to the young, ambitious, educated and enthusiastic reader who wants to begin to get know what science is, what it can and can't do, and how to make it happen.

To this end, this book is going to be playful, at times even irreverent. I present myself the 'curious sage'; as willing to learn as he is eager to teach.

I grant you, educated reader, permission to disagree, and hope this book brings you into consultation and discussion with myself and science, rather than any form of submission or capitulation.

I also give myself, as you, the permission to change my mind. This is a work in development, and my understanding of the history and philosophy of science, and how to teach it, will change over time – as I am hoping yours will as well, which is why I wrote this book.

I very deliberately use humour to teach in this book. I think you can truly know you understand something if you can make or understand a joke about it. so aside from making this book more fun, I hope it teaches you though humour.

I think perhaps one reason children learn so quickly is that they rarely waste any time feeling 'stupid' for not knowing something. Adults, on the other hand, are swift to punish themselves with bad feelings for not knowing. I'm going to assume you are not in this category, since you are reading this book, after all. but if I had a lesson for life I thought might help you in adult education, that might be it. don't waste effort making yourself feel bad about not knowing, though for most of us it's so automatic a response self-chagrin feels like no effort at all. But it is, and it robs you of the freedom and joy of seeing the world in a new way.