What science entails, beyond practical science

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The advent of science in the recent centuries has implications far beyond its practical applications, in our approach to understanding the world around and incorporating it into our way of life. This essay is aimed as a preliminary discussion on the theme.

1. How it all began

In the primitive world, as know-how began to be gathered the initial impulse was only to harness it towards meeting the basic needs. Gradually questions arose in the minds of people about the nature of the world around and in particular whether it has implications to human behaviour on a broader scale, at social as well as individual level. Since no coherent model for the happenings in nature could be thought of with the limited inputs at hand, a feeling evolved that nature is governed by something supernatural, or extraneous. The motivation then shifted to trying to identify how the supernatural intervened in the natural course, and to benefit from the understanding (both in terms of setting up goals—going to heaven, concern for consequences of actions during one's life to after death or rebirth, attaining *moksha* etc.—as well as appeasing the postulated agencies of the supernatural to gain functional benefits in everyday life). Many principles emanating from this model (e.g. good behaviour so as not to incur the wrath of the agencies of the supernatural) served also as fruitful devices on account of their potential to bring stability of the societies. On the other hand, to be sure, doubters of such models have existed through the ages. A notable instance in the Indian context would be the Charvaka tradition from around 600 BCE[1].

Incidentally though the Charvakas have

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[1] One oft quoted verse about them is

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yavad jeevet sukham jeevet, rnam
krtwa ghrtam pibet
bhasmibhutasya dehasya punaragamanam
kutah.
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As long as you live, live happily; take loan to consume ghee
Once the body is cremated how will it come back?

It is unclear whether this is an original formulation from the tradition or is a distorted version propagated by some detractors aiming to malign them, through what apparently appears an irresponsible advice on their part. Notwithstanding the status in this respect, it may be noted that even in that form it is far from being unreasonable, when seen in the right spirit. Contrary to the common (manufactured) perception the suggestion to take loan does not subsume you may readily default on them—in a stable society, in equilibrium, loans are possible only when there is some way of ensuring that they would be recovered, at least to a suitable measure. Thus the advice would normally incorporate also a commitment to repay the debt. It may also be pointed out that loan is advised for ghee, and not for alcohol for instance; consuming ghee was associated in the traditional society with keeping good health, which would in turn facilitate meeting one's responsibilities in life. — I may mention that these observations were made in a book by Sharad Bedekar, a prolific writer on related issues in Marathi, but do not have the precise reference.

been much maligned in the traditional milieu, their norms of behaviour were perhaps quite consistent with the modern day norms.

2. The scientific revolution

The scientific revolution (during 15th to 17th centuries) brought in, apart from the massive technological boons, the profound realisation that there is really no limit to the amount of knowledge that humans can acquire about nature, into its deeper and deeper manifestations, at macro as well as micro levels. One major consequence of this to the thought process was to reduce the role of the supernatural agencies. The scientific method that evolved alongside the technological revolution did not need to accord any role to the supernatural. Being able to arrive at explanations of phenomena in nature without recourse to the supernatural was seen to enhance one's ability to comprehend nature more effectively and to use the knowledge fruitfully in practice. As a consequence it also came to be incorporated as a crucial ethical principle in the practice of science — whatever the predilections of the individual practitioners in this respect, the scientific community expected that all reasoning and validation of knowledge be done through arguments internal to the system, not involving anything supernatural. For validation of knowledge material evidence was a fundamental criterion, and all inferences had to be based on sound, independently confirmed, principles of logic.

As it crystallized, the scientific method of acquisition of knowledge may be described as a system going through the following steps. It begins with observations concerning things or phenomena that we encounter, which often develop into ideas or hypotheses about how nature functions, in whatever specific context is concerned. The best hypotheses lead to predictions that can be tested in various ways. The most reliable tests of hypotheses come from carefully controlled experiments and logical analysis of empirical data. Depending on how well additional tests match the predictions, the original hypothesis may require refinement, alteration, expansion or outright rejection. If a particular hypothesis becomes very well supported, a general theory emerges.

This sets a model, or template (to use a more current word), for enquiry into the nature of things and validation of knowledge. A crucial point is that the method is of significance far beyond the everyday practice of science. Admittedly the method is not workable with equal facility in all contexts. There are a variety of difficulties, both at operational and theoretical levels. However there are some fundamental features that stand out and adopting them would stand us in good stead in our endeavour to acquire and validate knowledge concerning various aspects of life, that are not directly concerned practice of science itself.

3. Falsifiability

Firstly, testability of a hypothesis is of paramount importance. A hypothesis which cannot be tested (e.g. the earth being supported on the hood of a giant *Sesha*, a serpant) has no place in the body of knowledge, even as a candidate. 'Falsifiability' is viewed as a primary criterion — if you cannot have a test which has a possibility of throwing up a negative outcome in case the statement is to be false, the statement is worthless and may be safely set aside.

A colleague once raised the issue as to how can you rule out the hypothesis that "if a cat crosses your path something bad will happen to you"? If many people find it to be the case, it would be unscientific to deny it! The hypothesis is in fact not falsifiable, since what is 'something bad' is

not well defined, and subject to one's point of view; even in the case of any particular individual could vary from time to time. On the other hand, if the statement were something like "if a cat crosses your path your blood pressure will go up in the next five minutes" is a testable hypothesis, but such a hypothesis is unlikely to ever come up. The more common response on the part of most 'reasoning' people would be to say "how would the cat know?" or in other words rely on our sense of causality, which is a part of our accumulated knowledge about nature. The causality test would fail in respect of both the questions as above. However, while causality provides a good test in practical contexts there is a limitation associated with the fact that the phenomenon may be valid and yet one may not have means of knowing the cause.

4. Role of Questions

Second major feature is the importance of coming up with **Questions**, as a means of enhancing knowledge. Since a question can in principle be answered in a variety of ways (say blah, blah, for instance) we need also to have the means of judging the merit of the answers. When a child I had read a wise-guy story in which the king asks the number of crows in the town. The wise guy cites a biggish random number (2573). The king wants it confirmed, but is soon informed that to confirm it one would first have to first ensure that no crow should enter or exit the town pending the process. Abreast of the difficulty of the task at hand the king closes the matter appreciating the smartness of the wise guy and rewarding him for it. Even as a child I remember feeling that there was something wrong with the answer; if many mutually exclusive answers can be given that are just as good as the other, what is the merit of any individual answer? Whatever the merits or the amusement value of the story, as far as the issue of acquisition of knowledge is concerned it is a big no no.

The art of acquiring knowledge, whether in practical science or in other aspects of life, consists of asking good questions and being able to correctly evaluate the answers. A more typical and concrete situation involved in acquisition of knowledge is when together with the question you have a list of plausible answers, with a possibility and potential for expanding it, depending on the outcomes as they evolve in the process of testing the possible answers. This is not a very restrictive scenario, given that testing hypotheses is an important part of the process of augmentation of knowledge. If you cannot think of any possible answers to the question, there would be nothing to test, and no possible valid answers to the question. Of course, initial list need not be adhered to. You may happen to start with a question like what is the color of the bird that is flying across the garden, and while your initial list may consist of some primary colors, on closer inspection you may consider adding more of them or even add something like a shade between this and that.

The answers, and understanding on most issues, usually develop in steps. The subsequent answers may rule out the earlier answers; it is the brain that does the thinking and not the heart as was once thought! (The original idea would have been based on the response felt in the heart to various intense moments, and would have been 'confirmed' by certain tests, the idea had to be discarded following better understanding of biology, via other tests. The tests at any particular time can have limitations and the effects may be overcome by improved tests that better fit with a larger repertoire of observations. Questions like whether intake of vitamin C improves body resistance have seen a see-saw of

developments. On the other hand, in some instances later answers may subsume the earlier answers, as in the case of the relativistic mechanics incorporating Newtonian mechanics as a limiting case.

5. How and Why

There is a general cliche that science concerns itself with questions of 'how' while metaphysical pursuits are equipped to answer 'why' questions. But this is very misleading. It is indeed true that science concerns 'how' ? The issue about 'why' is rather complex. In some questions it is simply equivalent to 'how': 'why does the Earth go around the sun'? We use 'why' here rather than how, since the latter would normally correspond to description of the path (round, elliptical, oval etc.) whereas the issue involved is something else; but if you rephrase the question to "how does the trajectory of the Earth get determined?" and use our knowledge of Newtonian theory of gravitation we have the answer to "why the Earth goes around the sun". Many questions asking for 'scientific explanation' often get posed in this way, e.g., "why is the weather in Mumbai humid?" – which are equivalent to 'how' questions. On the other hand there are 'why' questions of other kind which are actually pointless: "why is man endowed with food sources on earth?". The anticipated answer typically is something like "by God's will", but it is meaningless as it is neither falsifiable nor testable. The question is pointless, since if there were no food sources, we would not be here to ask or answer the question. A question cannot treated as meaningful or deserving of an answer simply by the test of following rules of grammar. Other 'why' questions like "why are metals hard and vegetables soft?" have a mixed flavour depending on the context in which you view them; from the point of view of condensed matter physics it can be viewed as a 'how' question while in a lay context it is pointless — we simply accept them as their properties.

It may be clarified here that this is not a critique, or an argument against, asking 'why' questions. In practice we do need them and they are quite important. The point is that a 'why' question is good and meaningful basically when it can be converted into a 'how' question, perhaps an awkward one in some respects, and the 'why' is essentially a short or elegant form for the other formulation.

6. Pitfalls in the process

Let me begin this section with a quotation from Ibn Al-Haytham (Alhzen in Latinized form), the Arab polymath who flourished in the 10th century in Basra, Iraq, renowned for his work on Optics. By some accounts he is the earliest practitioner of the scientific method.

> The duty of the man who investigates the writings of scientists, if learning the truth is his goal, is to make himself an enemy of all that he reads, and ··· attack it from every side. He should also suspect himself as he performs his critical examination of it, so that he may avoid falling into either prejudice or leniency.
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> Ibn Al-Haytham

In practice however it is a far cry to meet such an obligation in pursuit of truth. The practitioners are all too human and are prone to biases of various kinds and these affect both the choice of the questions and the findings: it may be worth categorising these as follows depending on their sources.

1. Predilections arising from personal motivations.
2. Preferences borne out of professional considerations.
3. Biases arising from parochial tendencies.

6.1 Personal aspects

In the course of our early development we acquire a variety of prejudices, preferences, likes and dislikes. When a person engages himself/herself in scientific pursuits, the projects as well as reported findings may be affected by these.

By some accounts Copernicus was inclined to uphold the heliocentric theory out of faith in 'Sun God'. It seems also that some early works in bacteriology fudged the findings, purely out of personal convictions. These are instances where a bias led to breaking away from dogma. However, it could happen that personal biases lead to holding onto theories which may eventually be proved wrong, wasting a fair amount of work.

6.2 Professional issues

There are a variety of professional pressures which lead to withholding or fudging one's findings. Gauss was aware of existence of non-euclidean geometries before they were discovered independently by Lobachevsky and Bolyai, but did not come out with it as he feared that it would seem rather crazy and harm his reputation. Apparently the charge of the electron determined by Millikan by the oil-drop experiment was actually higher, but several successive experimenters adopted values closer to Millikan's, discarding readings which were away from that, and the value stabilized only over a period of 20 years.

When a researcher takes up a project there is also a pressure to bring out something 'interesting' out of it. An anthropologist is more likely to highlight positive qualities of the subject tribe (unless negatively disposed from the outset, when the focus would be on negative qualities). Such a thing seems to have happened in early studies in Indology, which later had a backlash where other authors began to aggressively fault the findings.

There are also issues about motivations coming from who is funding the research. Especially in medical sciences and environmental sciences, this is a major issue.

6.3 Parochial issues

Though not so much in mainstream science, in studies in history, anthropology, sociology, etc. parochial considerations are seen to affect research. Many projects are coming up on exploring beneficial effects of *gomutra* (cow urine), etc. and in the current environment, with heavy revivalist overtones, one would wonder how much credibility can be granted to the findings, which are in any case unlikely to be dealt with through open and healthy scientific debates.

7. In place of a conclusion

This discussion is meant to be a rudimentary exposition of what science entails, beyond direct aspects of scientific practice. There are inevitably many matters of detail involved; some of the issues about them are resolved at a technical or philosophical level, while others may be unresolved. Evidently there are also practical difficulties in following the method at an individual level, with the limited time and resources at one's disposal. One way of meeting this shortcoming would be to have a networking of people sharing the underlying ideas concerning scientific inquiry, and adhering to the basic principles with regard to validation of knowledge. Actively pursuing it as our *dharma* would no doubt bring further clarity. It would be of utmost importance however to sustain this valuable gift of science to the broader cause of charting our way through life, in the individual as well as social context. □