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Technical Note

Limitations of science and intolerance

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ABSTRACT

Modern sciences have some limitations, from scarcity of resources for experimentation to non-availability of data. In the vast universe of "hypotheses not tested," we have a small lot of proven theories. What is considered as a proven theory is based on certain assumptions; besides they can be colored by the intentions of financers. Truth evolves. Professionals can be proud of achievements but they should not be proud of the principles, which are falsifiable by definition.

Keywords: Methodology of science, Truth evolves, Falsification is inherent to science, Limitations of modern science

INTRODUCTION

From Macauley's education system to the Constitution of India (article 51A [h]) to the National Education Policy 2020 (cl. 4.23), a common endeavor is to "develop scientific temper!" Wikipedia explains "The term scientific temper is broadly defined as "a modest open-minded temper — a temper ever ready to welcome new light, new knowledge, new experiments, even when their results are unfavorable to preconceived opinions and long-cherished theories." A scientist, therefore, must expect and welcome knowledge (rather information) which may prove the long-cherished theories wrong. The scientist should not get emotionally attached to the previously accepted theories. However, in today's India, we find instances wherein the so-called educated people are not "modest open-minded" and become intolerant to other ideas. The current conflict between Indian Medical Association and the AYUSH ministry is a trigger point for this write-up; however, the points I wish to raise are more at academic level. In this article, an attempt is made to re-state the methodology of science – some premises and practices and to highlight the limitations of science, to make ourselves more modest and tolerant.

HISTORY OF SCIENCE

Curiosity is a characteristic of primates. Developing a better understanding of Nature was inherent to the journey from monkey to man. Efforts were driven by two instincts: (a) To reduce the stress of daily chores and create comfort zones and (b) to create better understanding of the divine designs. As hunter-gatherers settled into agriculture, men could share and collate their experiences and transfer the learning to subsequent generations. Ability to draw inferences improved. Mankind progressed. Various forms of energy (fire, waterwheels, domesticated animals) were harnessed, various techniques (bow and arrows, lever, screws, and gears, boats) were developed and honed. Giant structures like Egyptian pyramids and Chinese wall were

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created, none of them with the intention of establishing supremacy. Indians were able to predict the movement of stars and planets with considerable accuracy even before paper was invented. Ayurveda and Unani systems of medicine evolved around 1000 BCE. Indians had established two great universities — Nalanda and Taxashila. Then, around 5th century BCE Socrates, Confucius, and Buddha propagated their philosophies. Aristotle and Pluto explained the grammar of science and brought clarity of concepts. (They did not *invent* logic.) Plutonian philosophy was not at odds with religion; in fact, it is believed that his thoughts influenced Christianity and Islamic philosophy.

School syllabi in India would make us believe that most of the progress happened after Renaissance, whereas most of the abovementioned developments took place before Renaissance.

It was during the Renaissance period that Europeans came up with protestant philosophy and anthropocentrism. Science was at loggerheads with the Church. Rational thinking and religion were seen as opposites. The disrespect for the Church bloomed into disrespect for everything else, other civilizations, other line of thinking, other architecture, other craftsmanship, other "pathys," and so on.

METHODOLOGY OF SCIENCE

Hypothesis and theory

It all starts with the curiosity of mankind to find out why certain material behaves in certain pattern or why certain phenomenon Y occurs. A possible explanation is put forth in the form of X causes Y. Such proposition is called a hypothesis. Attempts are made to prove or disprove the hypothesis, either (a) by conducting experiments or (b) by collecting information available in this world. If proven right, the hypothesis becomes a proven theory or a scientific principle or simply "truth," (not *the* truth).

Conducting experiments requires resources and it is not possible to allocate resources to every hypothesis. There are seven billion brains on this planet and as many hypotheses! Hundreds of hypotheses from "cow-urine cures corona" to "*sagotra* marriage leads to congenital diseases" remain in the "not tested" category, because no one is going to allocate resources to disprove them. It is both illogical and against the scientific temper to reject a hypothesis because we do not have resources to disprove it. The hypothesis "Turmeric has anti-septic properties" also remained in the "not tested" category for centuries but was used effectively by our forefathers. Only when Dr. Raghunath Mashelkar did documentation, the hypothesis turned into theory, into truth! The people who allocate the resources for experimentation may have hidden or open agenda. Much of the research by pharmaceutical companies and agro (seeds) industry is openly motivated. We need to be cautious when accepting the results of such research. In this era of fake information and misinformation, attempt must be made to find out who financed the research and why. When experiments are conducted, condition *ceteris paribus* (If all other parameters remain unchanged) applies. We know very well that other parameters do change; not only weather and diet, but even the resolution, accuracy, and bias of the instruments used for experimentation change. After conducting the experiments, sometimes scientists are able to prove a cause-effect relation (bacterial infection leads to certain set of medical conditions), sometimes they can only gather empirical evidence (Those consuming high amount of nicotine have high probability of cancer). While announcing the end-result of a study, this aspect is often left unstated — or should I say, hidden.

On the other hand, when we rely on evidences available in nature, the information may be available amply or on rare occasions; for example, only when a solar eclipse occurs or when a case of neuromuscular atrophy is reported. Gathering information in such cases may take centuries. Until adequate evidence is found, the hypothesis remains in the category "hypothesis not tested."

Evidence based approach

Both above methods follow "Evidence based approach." The age-old maxim was "seeing is believing." However, soon the limitations of human eye (and ear etc.) became obvious. Therefore, instruments such as microscope and telescope were developed. Even with these instruments, man could not "see" black holes, they had to be inferred by the brain. Another fallacy of this maxim "seeing is believing" came to notice when astrophysicists realized that the rays from the distant stars take years to reach Earth and also change their wavelength in the course. Thus, when I "see" a star in particular direction, I can believe neither its location, nor its color. As the science progresses, as the body of knowledge expands, we need to depend more on brain and software and artificial intelligence, than on eyes. When data are analyzed, intentional or unintentional distortion is possible.

Cross-verifiability or falsifiability[1]

A theory proposed by a good scientist should be such that it can be cross-checked by anybody who wishes to do so. A hypothesis of the category X caused NotY (The comet did not strike Earth because I prayed to Lord Ganesha!) cannot be proven true. Nor be proven false! These are called unscientific statements and should best be neglected. Scientific theories "can be tested and proven false." Karl Popper used the term

1 Karl Popper makes a distinction between verifiability and falsifiability. Here I am using them synonymously.

"falsification" to denote this feature of old theories getting rejected in new light and new theories emerging. Theories in physics invariably get cross-checked or questioned by fellow scientists. (However, a theory proposed by Einstein could be tested only after 60 years).

Simulation packages used for verification require certain approximations or compromises. These compromises are not disclosed.

Early in the Renaissance period, Europeans introduced the Patent law. (Please understand the full significance of this 15th century Patent law. *All older civilizations had kept knowledge and money separate. Patent law married them*.) Americans developed a Patent system wherein the methodology adopted for the research and evidence were shown only to the regulating body and not to the competitors. Research methods are becoming increasingly costly affair and hence, even technically or logically falsifiable hypotheses are commercially not falsifiable. Therefore, much of the recent research in molecular biology and life-sciences cannot be verified by others. The statement about a patented molecule must be accepted by "having faith in the system!" Faith? The scientific temper goes for a toss!

TYPES OF TRUTH

Various statements are introduced to us as truth, even as universal truth. There are different types of statements and each one has different connotation. Let us try to understand.

a) Sun rises from east. This sentence is often showcased as universal truth. Nothing can be farther from truth. Actually "East" is defined as the direction wherefrom sun rises. The sentence is tautology. Often these definitions are taught to us in school in dubious manner. When teaching units of measurement (UoM) of time, we are not told that the duration of a day and a year are determined by the terrestrial bodies whereas the duration of an hour is arbitrarily defined by Europeans and has as much significance as the "*ghatika*" used by Indian civilization or some other UoM used by Babylonians.
b) All crows are black. This statement does not attempt to establish a cause-effect relation. It is considered true because (a) hundreds of people have sighted black crows and (b) nobody has reported white or green crow. The moment somebody from Madagascar or New Zeeland reports a red crow, we need to change the status of the sentence from true to false (or "partially true" based on your perception).
c) A and B are essential ingredients/factors for Y. (Sunlight and CO_2 are essential for photosynthesis.) Here again, only the condition "if NotA, then NotY" is proven. Why a solution of chlorophyl, water and CO_2 kept in a test tube in the sun does not perform photosynthesis? Such questions are not encouraged.
d) X causes Y. These statements come in different shades. A statement like "heat causes ice to melt" can be cross-checked by experiments by different people at different locations and different times. The statement "the gravitational force of moon causes tides in seawater" could only be inferred from the data available. Experimentation was not possible. A study done on X_1 is imposed on X_2; even learned doctors make this mistake without any mala fide intentions. (Conclusions from studies done on butter and cheese were imposed on ghee and many practitioners advised heart patients to stop consuming ghee, until Dr. Sharadini Dahanukar carried out independent research on ghee). Then, there are empirical results. When we say that "smokers have c+d percent probability of getting cancer while non-smokers have c percent probability of getting cancer," we are reporting facts, not a hypothesis! We are not stating truth, we are only inching forward towards truth. Who decides acceptance criteria for "d" in this statement to conclude that nicotine causes cancer?

Unfortunately, we use these "true" statements habitually, and we forget — sometimes, we are not even aware of – the conditions under which we accepted these hypotheses as truth.

Truth evolves: For centuries, atom was considered to be a solid impenetrable ball. There comes Rutherford who impinged atoms with X-rays to reveal that atom is hollow with most of its "weighty" matter concentrated at nucleus (and the location of the electrons in the orbit cannot be ascertained!). Tonsils were considered to be useless organs and thousands of boys in the 1960's underwent surgery to remove tonsils. Today tonsils are considered crucial for immunity. Capability of the instruments used for initial experiments improve over time and reveal data which differs from previous experimentation. The subject matter of study may itself undergo change; for example, cockroaches and bacteria develop immunity and therefore previously proven theories become void.

Karl Popper stated that this feature — "falsification"– is an essential characteristic of modern science. This is going to happen all the time.

FRONTIERS OF BODY OF KNOWLEDGE

Topics like Soul and God are beyond the realm of science and better be left as such.

What is meant by frontier? When scientists study in depth, they realize the limits – what can be known and understood and what cannot be gauged by modern science. That is the ultimate frontier, the author is referring to. Consider the

theories proposed by gentlemen Plank and Heisenberg in nuclear physics! These gentlemen together tell us that it is not possible to call an entity either as mass or wave and when treating it as mass, we cannot know its position and speed with any accuracy. Sunrays — are they continuous waves of energy or bundles of mass called photon? If sunlight is a rapid fire of photons, what is the mass and frequency of photons? These gentlemen did not say that they did not know, they said, "it is not possible to know!" That's a big statement! Does it not sound similar to the description of Brahman, which has no physical characteristics (*nirgun*) and therefore not measurable (*ameya*)?

Within the frontier, there is so much to be studied. We are still far away from what can be known. Two hundred years after Newton formulated the Law of gravity, Einstein predicted the presence of "gravitational waves" and then it took another 100 years to "detect" those waves. The 2017 Nobel prize for physics was given to three scientists who detected those waves. The Royal Academy Press Release, while awarding the Nobel Prize, said that this discovery is "opening up unseen worlds!" Point here is that there is so much in this universe that we do not know. That becomes current frontier of knowledge.

Scientists are still far away from their ultimate objective of unifying the electromagnetic forces with gravity.

But then common man is not so much affected by things like gravitational waves and God particles as they are affected by the developments in life-sciences. Here, we are facing two big walls — Ageing and Virus. There are two dozen or so diseases or medical conditions – from Alzheimer to Varicose veins – which are classified as age-related or ageing related diseases/ conditions, but we do not know why some people become "aged" at 60, some live happily till 100. Our understanding of virus is still elementary; we do not know if it is a living being or a chemical called nucleic acid. In last two decades, we have witnessed waves of certain types of viruses causing pandemic and thanks to modern science, we have successfully fought back. However, we cannot even predict the next wave, leave alone preventing it.

Allopathy is not able to cure some problematic conditions, for example, jaundice. Yet, when some other pathy claims that they can cure jaundice, allopathy doctors feel threatened. Not able to cure is fine, nobody expects you to be superhuman; but feeling threatened is inexplicable.

MORE WE STUDY, HUMBLER WE BECOME!

The first hurdle or roadblock to inculcating scientific temper comes in the high school when we learn what is known as "Anomalous expansion of water." The very word "anomalous" goes against the spirit of scientific temper. Trying to push the problem under the carpet! Why such expansion happens only in water and that too only at 4°C? Do we tell the fifth class students that our understanding of the matter is still imperfect? If a "believer" says that God has intentionally introduced this anomalous behavior to save fish from freezing, what counterargument does the scientist community have?

When the first nuclear test was carried out by American scientists in 1945, Oppenheimer spontaneously used a phrase from BhagwadGita (I am Death, the destroyer of worlds – *Kaalo asmi loka kshaya kritpraviddho*) to describe the explosion.

And finally, we come to the 21st century experiment by a body called CERN, which after meticulous and costliest experiments, proved the presence of a particle, which they named the God particle!

Isn't God an unscientific entity? Not measurable, cannot be tested and hence cannot be proven scientifically? Yes. Dr. Sriram Lagoo (a qualified allopathy doctor before becoming a cine-star!) had denounced the God and appealed to the people to "retire God!" What compelled these scientists to acknowledge the unscientific entity? Those having blind faith in modern science need to pause and reflect.

FUTURE OF SCIENCE

Two branches of applied science, engineering and medicine made tremendous contribution in 20th century and changed our life totally. That led us to a lifestyle of excessive consumption and excessive dependence. Climate change is an indicator of excessive consumption. Today, cautioned or frightened by climate change we are talking of "Sustainable growth." In next 20–40 years, path of sustainable growth will lead us to the Jain principle of *Aparigraha*. If it is not too late!

Corporates — pharmaceutical companies on one hand and Facebook, Twitter on other hand — are challenging the authority of the State and that is worrying us. Worry is not because of individuals like Elon Musk; these industries are acquiring a personality of their own — an adamant and confrontationist personality.

In medicine, (i) super-specialization in studies, (ii) reliance on machines for diagnosis, (iii) excessive dependence on pharmaceutical companies for treatment, (iv) increasing awareness of side effects, (v) alarming level of Hospital-induced-infections, (vi) realization of post-surgical ailments, and so on, are probable indicators that allopathy has reached its pinnacle.

In pure science: From reliance on eyes and reliance on hardware, we have transformed to reliance on software and Artificial Intelligence. So much so that now we are afraid of our own creations. Not just nuclear bombs and man-made virus. Those are aberrations of science and of course, we are

afraid of them. But we are now afraid on mainstream science outputs; we are afraid of steroids; we are afraid of excessive reliance on mobile phone and afraid of addiction to social media. On one side people want to insert chips in human body, other side some are afraid to give fingerprints to Aadhar card. People are paranoid that George Orwell's 1984 might become/has become reality.

Developments in *in vitro* fertilization, surrogacy, cloning, cryogenic storage of sperms and embryos, modification of human genes, etc., are questioning the paradigms of law and morality and shaking the foundation of the institution of marriage. Yuval Noah Harari in his book "Sapiens" says that a genetically modified entity (+fitted with chips and filled with steroids?) cannot technically be called homo-sapiens and therefore this is going to be the end of 240,000 years regime of homo-sapiens.

CONCLUSION

In this vast universe of "hypotheses not tested," we have a small body of proven theories. It is against the spirit of scientific temper to reject a "not tested" hypothesis; it has as much potential to be proven right as the hypothesis "turmeric is anti-septic!" Some of the proven theories may be colored by the financers, whereas all of them are vulnerable to falsification. Truth evolves. Scientist community (including brothers and sisters from the applied branches of engineering and medicine) can be duly proud of the achievements made with the application of scientific principles. However, scientists and professionals should not get emotionally attached to the principles; not so much attached that it creates hatred about other ideas. More you practice science, more you know about the limitations, humbler you become!

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