# Frames of science?

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*Good sense is the most evenly distributed thing in the world, for all people suppose themselves so well provided with it that even those who are the most difficult to satisfy in every other respect never seem to desire more than they have. It is not likely that everyone is mistaken; rather this attitude reveals that the ability to judge and distinguish the true from the false, which is properly what one calls good sense or reason, is in fact naturally equally distributed among all people. Thus the diversity of our opinions does not result from some of us being more reasonable than others, but solely from the fact that we conduct our thoughts along different paths, and consider different things. . .*

*Discourse on Method*
by René Descartes

The practice of science cannot be looked at merely in terms of its achievements. It also needs to be looked at in terms of the kinds of questions it gives priority to or the kinds of issues it sidelines. A professional scientist would obviously like to state that importance is given to those questions that are more critical for the progress of science/humanity or to those that interest the individual scientist more. While there is certainly some amount of truth in this, it leaves many questions unanswered. It seems to suggest that individual scientists work entirely independently and almost away from their social and political contexts. Scientific questions today are framed globally and a scientist always works with her peers. This global context of science is obviously not detached from the larger realities of the world in which we live.

I hope to argue in this essay that, like all social institutions, science is also a product of human history. A scientist is as much a product of this history as she is an agent in its making. Yet, the practice of mainstream science in India today is impervious to these issues. Instead we like to look at our enterprise and study/teach science in a completely ahistorical manner. By tracing one particular trajectory in the development of the current scientific practice, I will attempt to argue that this particular phenomenon is itself a product of a certain history. I will further attempt to explain the context in which mathematics acquired its special position as the edifice on which all basic sciences could be built.

## The development of science

Given our colonial histories and the effect that it has had on scientific education in India, I choose to specifically deal with the history of modern science through developments in Europe. In his well-known work *Science in History*, J. D. Bernal identifies three significant phases in the history of Europe that significantly shaped the birth of modern science. These are phases that saw several changes in the socio-political terrains of Europe.

### *The first phase (1440–1540)*

This phase coincides with the Renaissance and Reformation in Europe. Politically, it was a time of shift from the feudal form of graded loyalties to that of absolute power of the prince. Economically, it was a shift from feudalism to a more capitalist form of economy, where the markets were dominated by money payments. Renaissance and Reformation involved a change in the system of social relations, moving from a hereditary system to one based on buying and selling. It was also the period of assertion of religious independence as reflected in the Lutheran and Calvinist Movements, and also of fierce social strife as evidenced by the Peasants' wars of 1525–26 or the revolt of the Anabaptists in 1533–35. Thus the power of the Church declined and loyalties to the Church concurrently reduced. This had a revolutionary effect on the arts and humanities.

The royalty, whose political power depended on the merchants, became the new patrons of art, architecture and music, which were no longer required to be in the service of the Church. Artists began to experiment with new methods, materials and media. They became knowledgeable about mining and metallurgy. They were also consulted by the kings and merchants regarding construction and architecture. Artists also developed the idea of vision and perspective. Three-dimensional objects began to be studied in great detail. As a result, knowledge of human anatomy, physiology, mechanics and dynamics grew parallely. One of the most prominent examples of the versatile talents of this period was Leonardo da Vinci.

Towards the end of the sixteenth century, a critical break happened in the old trade system. Egged on by ambitious merchants in search of new markets, the royalty of Europe patronized the Great Navigations. The discovery of the Americas and the opening up of the East to trade brought about an economic revolution in Europe and also completely altered the position and relevance of science. Not only did the navigations spur rapid developments in ship-building and the allied disciplines, but they also revolutionized the field of astronomy. Successful trade across sea routes required more accurate astronomical measurements. Building from purely aesthetic considerations, Copernicus proposed a heliocentric model of the universe that well explained the position of planets and stars in the night sky. This proposal, directly challenging the earth-centric notion of the universe upon which was based the power of the Church, was however to become the turf for a long struggle between the philosophers and the Church. The Copernican proposal was a paradigmatic shift in philosophy and science, with far-reaching scientific and political implications.

### *The second phase (1540–1640)*

The success of the Great Navigations greatly increased the economic and political power of the business class in Europe. They began to independently fund technological advances to increase production and maximize profits. Thus also came into existence the 'experimental philosophers' or experimental scientists as we call them today. Colleges for universal scientific education were set up for the express purpose of improving navigational studies. In the field of astronomy, Tyco Brahe and Johannes Kepler not only provided legitimacy to the Copernican model, but the latter also attempted to prove it with the use of geometry. With the invention of the telescope, Galileo provided empirical proof for the heliocentric model of the universe. The Church on the other hand, saw these as dangerous developments and began a series of repressive moves aimed at stifling all challenges to its power (the Counter Reformation). The trial of Galileo brought into sharp relief this struggle between scientific knowledge and religious doctrine.

In direct response to the socio-political context of the times, two of the greatest thinkers of all times, Francis Bacon and René Descartes, presented a vision for the possibility of new knowledge. Bacon emphasized the practical aspect of all knowledge, knowing that all empirical proof would strengthen his hands in the struggle against the Church. Thus he proposed the inductive method – collecting materials, performing experiments and accumulating a large amount of empirical results on the basis of which an inference could be made. In essence, this 'scientific method' continues unchanged even today.

Descartes on the other hand, belonged to a different school of thought. Trained in logic and geometry, he stressed the importance of rational thought as the route to all that is rationally knowable. Experiments were only auxiliary to this 'deductive thought'. In an attempt to avoid a run-in with the Church, Descartes also proposed an extraordinary method of division of the universe. According to his formulation, the universe could be looked upon as being made of two parts, the physical one and the moral one. Science, according to Descartes, would only deal with the physical world, the world of 'measurable observables'. Descartes' legacy lives on to this day too, splitting the world of philosophy down the middle and creating two separate, apparently unbridgeable realms of knowledge.

### *The third phase (1640–1690)*

The third phase in the scientific revolution coincided with a phase of political compromise and stable governments in different countries of Europe. The severing of science from philosophy ensured that science became free of religious interference as long as it did not stray into the 'moral world'. Science too consolidated. Governments and ruling classes that had already tasted the spoils of colonization encouraged scientific progress, even setting up independent scientific societies to further the cause of independent scientific research. The aim was unabashed power and profits. Science, alienated from philosophy, became inextricably linked to these goals. It must be noted though that the foundations of all the basic sciences were also laid during this period – corpuscular and wave theories of light, developments in the field of dynamics and mechanics, discovery of microbes, invention of calculus, all owe their successes to these remarkable and rapid turn of events.

Arguably, for our discussion, the most noteworthy of all still were the developments in celestial mechanics. Greater navigational routes and sea trade demanded greater accuracy in navigational skills. For most part, voyagers and navigators had depended on the Arabic method of trigonometry to chart their course across the expanse of the ocean. From Copernicus to Galileo, arguments in favour of the heliocentric view of the universe had grown, but it was left to Newton to provide the next paradigmatic shift that not only ushered in a new era in astronomy, but also fundamentally altered the practice of science. Using calculus, Newton showed that it was possible to describe physical reality as a mathematical entity. Conversely, physical realities could be derived from mathematical equations. He also showed that by measuring changes in an entity it is possible to arrive at the entity itself. Thus force depended on change in motion rather than motion itself. This was the new 'dynamic way' of looking at the world. So successful was the Newtonian model, and so complete the power of the man himself within the scientific establishment as to quell all competition, that it began to be universally accepted that the universe was governed by simple mathematical rules. This became the cornerstone of all scientific theories of the physical world, and the acceptance and success of theories became linked invariably to their mathematical verifiability. Mathematics had been plucked from the realm of philosophy and pure reason and firmly placed in the realm of science.

## Conclusion

The separation of the universe into the physical and moral worlds by Descartes was a clever survival strategy that gave a new lease of life to the sciences. But in doing so, it also tore asunder the intimate relationship that existed between the epistemic and practical goals of science, between philosophy and the practice of science itself. The liberation of science from religious interference came at a heavy price. This, along with a concomitant spurt in a capitalist economy driven by the desire for profit, saw technology gradually gaining in stature and power over the basic sciences. The parallels in the present world are hard to miss.

The Newtonian legacy too lives onto this day in the hierarchies between the sciences, in the manner in which science is both introduced and taught in our classrooms. Emphasis on technical training and super specialization has alienated science from its social universe. By doing so it has also avoided accountability to the community that to begin with supports the scientific enterprise and for whose benefits it claims to work. But scientific instruction into the methods without the accompanying rigours of training in logic and rationality (which continue to be 'relegated' to the field of philosophy), or the buttress of knowledge about the socio-historic-political contexts of the times has led to the production of technically skilled individuals taking over the mantle of the scientist–intellectual. The culture of blinkered experts carrying only the specialized tools of their trade can seriously undermine progress in the basic sciences in this country. Emphasis on technology and the tendency to value everything in terms of the market have only further skewed the field.

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