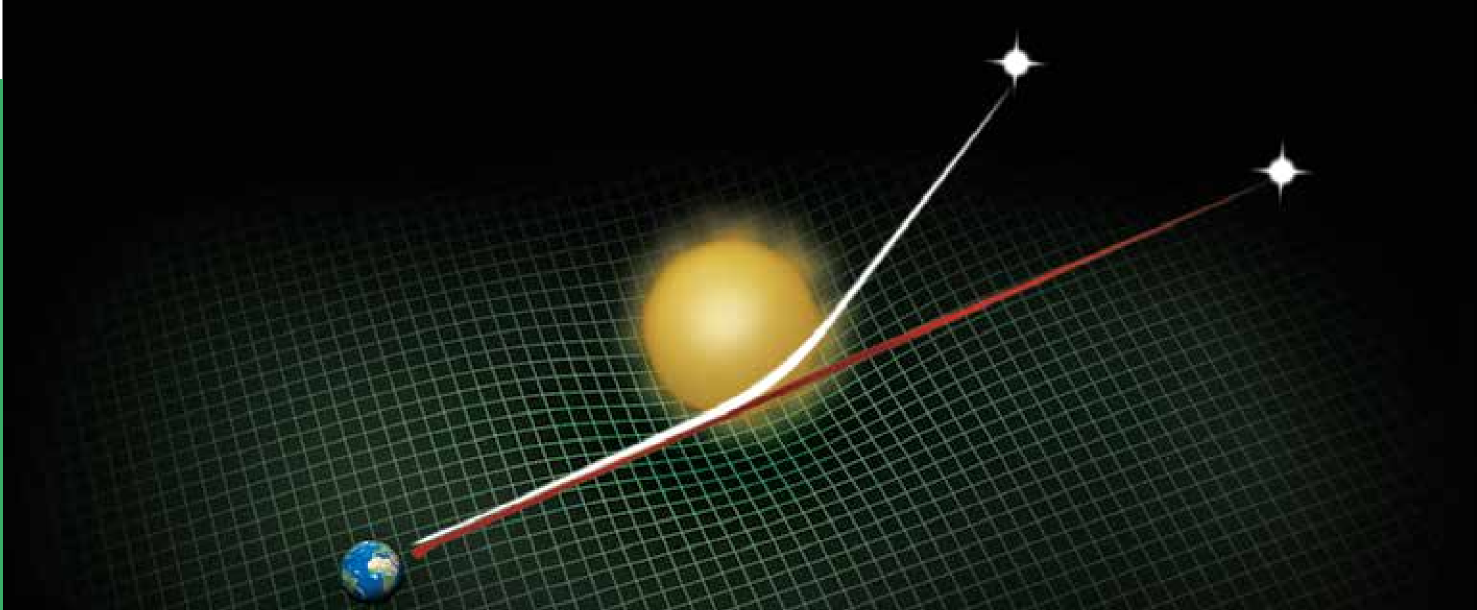

WHY DO EXPERIMENTS?

BHAS BAPAT

We are bequeathed a legacy of clever and painstaking experiments by the pioneers of modern science. In the age of information overload, it is prudent to consider why we need to dirty our hands doing experiments, instead of merely depending on processed information to push the frontiers of science.

Science is driven by human curiosity; curiosity to know why things happen the way they happen, or in other words, to understand how nature works. This curiosity gets channelised in many ways, two of which we can readily identify with. The first is to make careful observations of phenomena, identify factors affecting a particular effect or outcome, and then attempt to control the outcome by tweaking the influencing factors, thus establishing a cause–effect relationship. The other is to predict a cause–effect relationship by applying logic about how things should be without necessarily working out the ideas in practice. In the formal world of science, these two approaches are readily identified as experimental research and theoretical research respectively. However, contrary to common belief, these are not distinct streams, nor is one cleverer or purer than the other. Instead, they complement and supplement each other. An experiment (or a series of experiments), is no good if the inferences drawn do not help us build a more general or wider understanding of phenomena. Likewise, a theory is no good if it does not explain a set of observations or make correct predictions about things not yet observed. Very often, though not always, a theory is based on axioms or postulates that are a distillation of inferences based on observations. Humans are naturally trained to believe only what they are able to perceive with their five senses. A non-scientist is therefore likely to ask 'But, is it real?' for something that a trained scientist will accept as second nature, even if it can't be seen or perceived with the senses. A case in point is the microscopic world. We believe in atoms and sub-atomic particles, though nobody has really 'seen' them. This is so because we have been able to build an edifice of knowledge by making certain postulates,

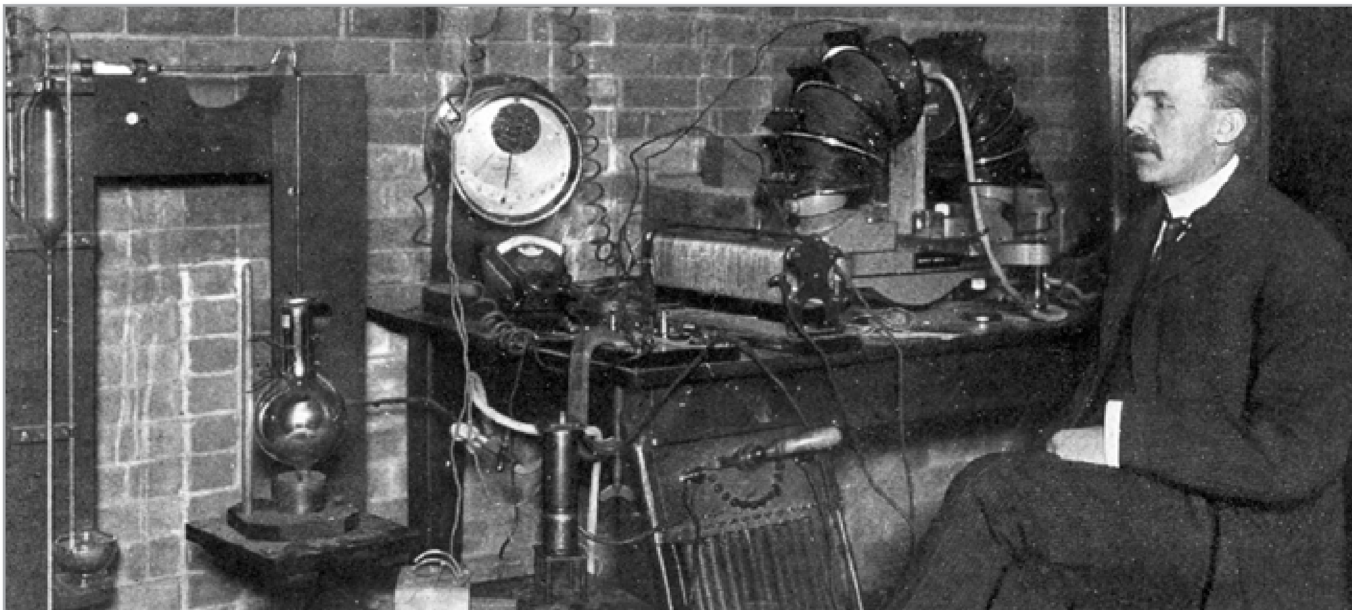

Figure 1. Ernest Rutherford with his apparatus for studying radioactivity. An apparatus is merely a tool that puts out some numbers. It is the inferences drawn from the numbers that may have far-reaching implications in science, as they did in this case. They also brought Rutherford fame by way of a Nobel Prize. Source: Contributor unknown, published in 1939 in Rutherford: being the life and letters of the Rt. Hon. Lord Rutherford, O. M - http://wellcomeimages.org/indexplus/image/L0014629.html. Wikimedia Commons. License: CC-BY. URL: https://en.wikipedia.org/wiki/Ernest_Rutherford#/media/File:Ernest_Rutherford_1905.jpg.

which appear reasonable based on experimental observations, and then applying logic.

So, experiments serve three main purposes. First, obtaining information about phenomena that have not been understood before, which in turn assists the development of a theory pertaining to those phenomena and enhances our ability to make predictions. History of science throws up innumerable examples. The development of the concept of an atom and the particulate nature of matter and the associated concepts of heat and temperature are largely based on insightful analysis of chemical and physical reactions. The second purpose of experiments is to verify or reject the predictions of a theory. Some outstanding examples of this include the demonstration of the quantisation of angular momentum of atoms by Stern and Gerlach, and the measurement of the bending of light due to the sun's gravitational field by Eddington and his collaborators. In more recent times, the discovery of various particles in high energy particle collisions has confirmed the predictions of the Standard Model. A famous experiment that rejected a popular theory is the Michelson Morley experiment; it sounded the death knell for the all-pervading ether. The third purpose that experiments serve is paving the way for application of science for societal benefits. There are simply too many of them to list, but one outstanding example is the Haber process that enabled fixation of atmospheric nitrogen as ammonia which plants could use as a nutrient - a process that was the key to scaling up of agricultural production to meet the burgeoning population and associated food shortages. One field that has benefited enormously from relentless experimentation, in diverse streams of chemistry and physics, is medicine. Diagnostic tools such as biochemical analysis, ultrasonography, X-ray, NMR, minimal invasive interventions and therapies are a fall-out of a series of experiments, in domains where theory is far too complex and intractable, if not unknown. Many scientific discoveries have been serendipitous, and it is easy to see that the more you tinker, the more likely you are to hit something big.

Bhas Bapat is a physicist working at the Indian Institute of Science Education and Research Pune, and has interests in school science education. He can be contacted at bhas.bapat@gmail.com.