Quantitative vs qualitative: Which side of the fence?

C. P. Rajendran

Kelvin was a prodigy. He got admission to Glasgow University at the tender age of ten. He had to use a pseudonym to publish papers so as not to embarrass his seniors. He became an authority in every branch of physical sciences and on the theoretical aspects of electromagnetism, thermodynamics and optics. Then he tried to calculate the age of the earth. He went seriously wrong in this exercise. This was back in the last leg of the 19th century, before radioactivity was discovered. In fact, many researchers were trying to speculate on the age of the earth in those days. Bill Bryson in his book *A Short History of Nearly Everything*, mentions an example of Archbishop James Ussher of the Church of Ireland, who suggested that the earth was 'created at midday on 23 October 4004 BC', based on an 'in-depth' study of the *Bible*. Kelvin, however, a descendant of the Newtonian generation, based his calculation on the second law of thermodynamics, although he did not foresee the earth's radioactivity as a continuous source of heat. His logic was that the sun would have exhausted its fuel, had it been very old, and therefore the planets cannot be that old. He got a minimum age of 20 million years and a maximum of 98 million years. But Kelvin's calculations were off-way off, although he had employed a physically sound approach and used the appropriate equations. But there was a hitch because already, geologists were finding the Cambrian strata (deposited 500 million years ago) with fossils that were much older than the age that Kelvin had come up with. Kelvin refused to appreciate the geological insights till his death. Later the radioactive techniques proved that the earth was 4.5 billion years old – an experimental result that matched the palaeontological and geological observations. I quote this story to show the snobbish inhibition in the academic circles, now as then, and that the results in science can be achieved only by mathematically rigorous techniques.

The same thought must have governed Ernest Rutherford, who made a strong statement that barring physics, the rest of science is stamp collection, notwithstanding the irony that he got the Nobel Prize in Chemistry not in Physics. It is said that Rutherford used to fumble with his own equations midway and look askance at his students, who would then work them out for themselves (which only means that he was not terribly good at mathematics). I think it was Enrico Fermi who famously said, 'explain to me in equation', when he was told that the barbershop was located three blocks down the street. Physicists tend to look down on the observational sciences like geology, biology and botany as being 'qualitative'. Or look at the statement that science is based on experiment, forgetting the fact that science is equally based on observation. There certainly exists a cultural divide – a large gap between two approaches to problem solving: the Newtonian and the Darwinian. Earth sciences (geology) and to some extent cosmology (planetary geology) can be compared because these branches of science have to deal with unique events and the systems cannot be replicated. Would it be possible to force unilaterally a Newtonian framework on these sciences? Let us frame the question this way: is it possible to reconcile these approaches and build a synergy and synthesis? That is doable and we are already moving in that direction with our interdisciplinary approaches where methodological pluralism must be the password. The synergy of these approaches is facilitated also by the technological breakthroughs in instrumentation. In fact, technology has revolutionized the way we gather observations in the fields of geology and biology.

Let us focus on geology, a field I am familiar with. There is a general lack of appreciation of its capabilities as a preeminent tool for scientific enquiry. The neglect of geology is primarily because of the notion that it is a derivative science. It consisted of a few thumb rules, and it is perennially haunted by incompleteness of data, lack of direct observation and at many occasions has to content even with lack of experimental data. In contrast, physics is a paradigmatic science – always sure of the end result and of the predictive knowledge of the world (notwithstanding the uncertainty in quantum mechanics and the unfalsifiable string theory). However, it should be noted that geological reasoning follows a distinctive methodology of logical procedures and reasoning to understand nature. I would argue that this is a preeminently suitable method to understand the behaviour of systems that are inherently complex, and whose initial and governing conditions are not known. For instance, a geologist looking at a rock outcrop assigns different grades to various aspects of the outcrop to understand the outstanding patterns. This is like Sherlock Holmes asking his confidante Watson whether the dog barked in the night. Maybe the dog did not bark at all. A lesser imaginative person might have dismissed this as a 'non-event'. But then, that is the difference between a Sherlock Holmes and a run-of-the-mill police inspector. Even a 'nothing' or a non-incident can be a clue for an imaginative detective. Any incident should be weighed in the given context. You are like a detective trying to build circumstantial evidence against the defendant. The invariable data gaps are filled with interpretations and reasonable assumptions lighted by logical clarity.

Charles Darwin went around the world with a book written by his mentor Charles Lyell, *The Principles of Geology*. It is possible that Darwin probably got the idea of 'incremental change' from his reading of geology, which he applied profitably to develop his theory on natural selection, which is undoubtedly one of the greatest insights emanated from human mind. Richard Dawkins thinks Darwin's theory of natural selection would work anywhere in the universe, but not the relativity theory of Einstein. There may be at least one universe within this ten to the power of five hundred universes (the string theory demands such huge numbers) where the physical constants are different and the relativity theory might break down, but not the natural selection. It is not just universal, but multiversal, Dawkins might say. Geology can be considered as a preeminent example of integrative science consisting of a variety of logical techniques in finding solution to problems that are mired in contingencies and complexities (see

Frodemann, R., *Geol. Soc. Am. Bull.*, 1995, **107**, 960–968). The role of climate feedbacks in tectonics is a case in point, which essentially questions our erstwhile reductionistic approaches to such problems, especially those based on the idea of initial conditions (chicken or egg problem). Geology is too descriptive, critics allege. But one must remember that building a narrative context for the findings is an essential part of the exercise, because most of the geologic problems are place-centric and more often than not, there are more than one equally plausible way of explaining a phenomenon (e.g. climate change – it may be equally possible to argue for a lack of change. The absence of sea ice in the Arctic can be interpreted as due to changes in the wind pattern and not due to global warming).

Whatever complex models of natural processes we make, we will never have the 'physics-level' predictive accuracy, so says physicist-turned-environmental scientist, John Harte (see his article in *Physics Today*, October 2002, 29–34). So what do we do? Does this postulation mean that the natural systems are not amenable to prediction? John Harte suggests a middle ground to achieve the predictive power for the natural systems so that the strengths of both Newtonian and Darwinian approaches are combined. Consider an earth-like planet somewhere in the universe, where we expect similar geological processes mediated by water take place. At the fundamental level, these processes, as on the earth, should follow scaling laws. This is fundamental to the processes, whether it is occurrence of earthquake or delta formation or even species diversity. Such power-law relationship reflects self-similar pattern. That natural processes are not truly random and they follow a pattern, is the crux of the matter. There is a spatial and temporal pattern with a certain self-criticality attached to it. It follows that understanding the past temporal and spatial pattern will help improve our ability to predict them (does not mean 'physics-level prediction'). Even an extreme event of the meteorite rain that killed the dinosaurs at the K–T boundary follows a cyclicity, as the new study claims. Therefore, the fundamental work that is required is to collect data on spatial patterns over longer intervals of time through large-scale field surveys and also document the past temporal changes. And geology facilitates that, the greatest contribution made by this branch of science to human knowledge. Now we will have to continue this tradition also in understanding the processes on other planets. What I mean is that this method of study will continue into 21st century and beyond. Incidentally, the recent drilling in the San Andreas fault suggests that the existence of soft rock-like chalk at depth is the reason for the lack of earthquakes on that part of the fault. This then is geology indeed. No amount of modelling without this key factor plugged in will provide you the true picture.

Coming back to Kelvin, his mistake was that he forced a Newtonian approach on a problem that required also inputs from historical analysis. Unlike the naturalists of the 18th and 19th centuries, we have the advantage of powerful computing abilities to model the basic data. Both Newtonian and Darwinian approaches have their individual roles in spurring our quest to understand the natural processes as they are complementary to each other. Remember that today it is possible to crank up complicated algorithms that mimic natural systems or generate patterns that you would want them to be. But the question is whether they move us closer to the reality or to a myth. Ask a wine maker, (s)he will say, 'blending is the key to success'.

C. P. Rajendran is at the Centre for Earth Science Studies, Akkulam, Thiruvananthapuram 695 031, India.
e-mail: cp.rajendran@yahoo.com