EDITORIAL

# *Learning Science*

As a boy of five, Raghunatha Tarkashiromani, one of the most astute logicians that medieval India produced, was asked by his widowed mother to fetch her some fire from the nearby Sanskrit school. When Ragunatha requested one of the students working in the kitchen for fire, the boy, deciding to have some fun, picked up a piece of burning charcoal in a ladle and asked Raghunatha to 'catch' the coal. Raghunatha had no container with him, but he had the presence of mind to scoop up some of the sand lying around and receive the burning charcoal on it. Vasudeva Sarvabhauma, the reputed master of the school, was struck by Raghunatha's quick wit and forthwith requested his mother to put Raghunatha under his charge for formal schooling. Raghunatha, of course, was not going to let his teachers do all the questioning. Even as he was being introduced to the alphabet, he had his first question ready, 'Why does *ka*, the first letter, precede, *kha*, the second?' It would surely have required some fundamental linguistic skills on the teacher's part to answer such queries, but the boy's future career would not have been hard for him to guess.

The new school of Nyaya, logic, that Raghunatha presided over was known for its great intellectual rigour. But it was constrained by its own presuppositions about the nature of the physical world. For science to flower, the ability to make generalizations had to be wedded to 'irreducible and stubborn facts' obtained by empirical observation and experimentation. 'It is this union of passionate interest in the detailed facts with equal devotion to abstract generalization which forms the novelty in our present society,' noted A N Whitehead. 'The main business of universities is to transmit this tradition as a widespread inheritance from generation to generation.'

Sir C V Raman, the first Asian to win the Nobel Prize in physics for his discovery of the change in wavelength of light passing through different media—an effect, named after him, that provides important evidence of the quantum nature of light—was one mind that brilliantly harmonized the spirit of observation and generalization. And Raman was a man of protean interests, besides being a gifted communicator. In one of his radio talks on popular science on mollusc shells, he urged his listeners to get infected with 'the enthusiastic admiration which I feel for nature's handiwork in this field'. 'The study of shells, fascinating in itself, becomes doubly so when we regard it, in its correct perspective, as the study of one of the most ancient forms of life on this planet of ours,' he continued. 'The forms, the sizes, the colours, and the architectural characters of shells are manifold in their variety and charm. But the mystery and the interest deepen when we ask ourselves why and how the humble mollusc builds for itself these forms of beauty.' Once one gets interested in shells, Raman observed, one soon realizes that their numbers are incredibly large—more than a hundred thousand species are known—and they range from microscopic sizes to half-ton clams big enough to serve as bathtubs. 'The variety of form and colour offered by molluscan shells is unsurpassed by any branch of biological life, so much so that the study of the subject becomes an adventure in itself.' And the adventure is universally accessible as molluscs can be found in one's garden as well as in ponds, lakes, and seas.

Shell enthusiasts have their basic lessons in chemistry when they realize that the shell is the same material as chalk and turns to quick lime, calcium oxide, when burnt—they were indeed widely collected and burnt for this purpose only a few decades ago. The chalk crystals in their calcite form are mixed with organic matter that gives the shell its resilience. The rare aragonite form of chalk deposited in numerous microcrystalline layers makes for mother of pearl and in combination with the organic horny substance is responsible for its resistance to corrosives. Even a pearl has this structure and is primarily chalk!

This summary of Raman's talk gives a glimpse into the scientific mind that is curious about mundane objects, delves into their properties, finds associations that escape others, and discovers novel uses for them. But this alone does not suffice. In the physical sciences the generalizations that follow observations have to be expressed in the language of mathematics. And as J B S Haldane puts it, 'Most normal children are thoroughly bored by mathematics at school, and no wonder, considering how they are taught.' 'One reason for this boredom,' Haldane adds, 'is that they are given hopelessly artificial problems to solve, instead of problems which arise from their daily life.'

Richard Courant was one mathematician who made the subject interesting. 'For years the attic of the Courant house was filled with wire frames used in the soap film demonstrations' of Plateau's problem, which were 'a source of endless fascination for the grandchildren' several of whom went into 'mathematics and related pursuits'. Incidentally, Plateau's problem involves finding the surface of smallest area bounded by a given closed contour in space. A physical solution to the problem is provided by withdrawing a wire frame shaped in the given contour after dipping it in a liquid of low surface tension—say, soap water. Thus, if one uses a cubical frame one obtains a beautiful soap-film system of thirteen surfaces meeting each other at angles of a hundred and twenty degrees.

David Kolb and Bernice McCarthy have identified four different types of learners: (i) the imaginative, who perceive information *concretely* and process it *reflectively*; their favourite question is 'Why?' (ii) the analytic, who perceive information *abstractly*, and process it *reflectively*; their favourite question is 'What?' (iii) the common sense type, who perceive information *abstractly* and process it *actively*; their favourite question is 'How does this work?'; and (iv) the dynamic, who perceive information *concretely* and process it *actively*; their favourite question is 'What if?' Researchers have also pointed out that 'students who do well in school tend to be the ones that learn either by listening or by reading. The focus on these two senses, especially at the high school level, tends to marginalize the tactile and kinaesthetic learners.' An inclusive learning system would be so designed as to help kinaesthetic learners learn 'by participating, moving, and talking', and tactile learners 'by doing, touching, and manipulating'.

It is important how science is taught for, as Bertrand Russell reminds us, 'the majority of our opinions are wish-fulfilments, like dreams in the Freudian theory. The minds of the most rational among us may be compared to a stormy ocean of passionate convictions based upon desire, upon which float a few tiny boats carrying a cargo of scientifically tested beliefs.'

'The scientific mood is especially marked by a passion for facts, by cautiousness of statement, by clearness of vision, and by a sense of the interrelatedness of things.' Cultivation of this mood involves rigorous discipline. The way of science 'teaches individuals to persevere even in the absence of enthusiasm, to avoid self-deception, and to gain control of their thoughts and attention; it trains them to persist until they grasp a principle rather than stopping at partial solutions; it teaches them to notice how events are linked, to identify structures and rhythms not immediately apparent, and to leave behind a familiar world in order to visit another one, strange and impersonal.'

The discipline required for scientific pursuits is in many ways akin to the discipline needed for mastering Vedanta. By promoting genuine scientific learning we might also be aiding individuals to grow spiritually. And that, surely, is no mean gain.