On the way to innovation

B. A. Dasannacharya

There is a great amount of buzz nowadays about innovation, implying that it is at the core of technological and scientific growth. On the other hand, there is also another strong view, especially among research scientists, that science should be problem-driven. While both are correct in their own framework, either one is not independent of the other; they complement one another with each standing on the shoulders of the other. With a background of an experimental physicist I find that this is particularly true of physics, though I imagine this to be so in all areas of science. I have the backing of no less a person than the 'pitamaha' of modern Indian science, Jagadish Chandra Bose, physicist and botanist. According to him, in order to do science of good quality one must have three conditions satisfied. First, one must have a good imagination, since the best experiments are first done in one's mind. He, however, warns that wild imaginations of the mind can lead to disastrous conclusions. Therefore, imagination has to be tested on the battleground of experiments. This, he says, requires the other two conditions to be satisfied. First, one must have a well-equipped laboratory and secondly, one must have the ability to design and build sensitive and accurate instruments. He himself built some of the best equipment in the world between 1895 and 1915, both for his microwave experiments and for measurements of growth of plants. He built equipment of such sensitivity that Gerta von Ubish (University of Heidelberg, Germany) questioned the very possibility of building it, as she could not replicate the same. Rajinder Singh[1] examined this in depth and came to the conclusion that when Bose did his experiments, Germany had already an industry to make scientific instruments on commercial scale, with standardized methods which were presumably not easily adaptable to reproduce the devices which were instrumented by precision craftsmen and jewelers in India under his personal supervision. This underpins the fact that frontline equipment and experiments need individualized development of the tools of the trade. I can hear some of my colleagues reminding me that times have changed. I hope to address this by giving some recent examples later.

Sticking with the Indian physics scene for the time being, chronologically the next big name is of C. V. Raman. Both Bose and Raman were driven by their desire to understand Nature. The experiments they decided to do were a result of this desire. However, Raman was different in the sense that he did not develop sophisticated instruments of the kind that Bose did. But Raman was a first-rate designer of his experiments. I have already referred to Bose saying that an experiment is first done in the mind. Raman was excellent in translating this 'mental' experiment to a 'real' one using the simplest of means. His early studies on the veena and the tabla and later use of, what he called, the pocket spectroscope bear testimony to this. The first observation of the Raman effect was indeed made using a pocket spectroscope, to be then confirmed using a commercial Hilger spectroscope[2]. Having said this, let me note here the views of some people that after Raman, optical studies, including spectroscopy would have flourished more in India if we had produced our own sophisticated optical instruments, including gratings, detectors, etc. to consolidate the lead given by Raman. As these things became more expensive, we simply fell behind.

Homi Bhabha, a trained mechanical engineer turned theoretical physicist from Cambridge, UK, joined the Indian Institute of Science, Bengaluru in 1939. Along with theoretical studies he started cosmic ray experiments using balloons and detector payloads. How this initial beginning grew into the Tata Institute of Fundamental Research, Mumbai, is a story well told in Venkataraman's book[3]. He describes how equipment was generated for experiments as and when required instead of waiting for someone in the advanced world to develop it. The most magnificent example of this is the building of the astronomical telescope at Narayangaon near Pune by Govind Swarup's group. Experiments are conducted today by both Indian and international scientists using this facility.

Another example born out of Bhabha's extensive atomic energy programmes, is the development of thermal neutrons' scattering at the Bhabha Atomic Research Centre (BARC), Mumbai. With the advent of nuclear reactors in the forties, neutron beams became available for studies of condensed matter. B. N. Brockhouse in Canada was one of the early scientists to realize the importance of neutrons in revealing the nature of atomic motions in the condensed phase. P. K. Iyengar worked with him for about a year and a half in 1957–58. On returning to India, he initiated neutron scattering experiments at the country's first reactor Apsara, by building a neutron diffractometer and an inelastic scattering spectrometer. He created a school of neutron scattering in India entirely based on indigenous instruments for an entire range of experiments at the next reactor Cirus, and the group soon found international recognition with peer groups. A number of scientists from several Asian countries were trained and many neutron instruments were sold. An instrument of a novel design and superior energy resolution[4] was installed at the world's most powerful pulsed neutron source, ISIS, at the Rutherford Appleton Laboratory, England in 1982. In return, Indian scientists were given access to the use of all neutron beams there for free. When the next bigger reactor, Dhruva, was built in the eighties, the neutron group at BARC installed a whole new suite of high-quality instruments. This was declared a National Facility and made available to scientists from anywhere in India, all expenses paid, under a joint scheme between DAE and UGC. More than 200 scientists from all corners of India have become users of neutrons today. An active community flourishes doing experiments in physics, chemistry, biology and engineering, both in pure and applied aspects.

On an international level, the importance of this type of development can be appreciated by looking at the Nobel Prizes for physics. The list is long and the following shows some of them starting from the 1980s.

- Kai Siegbahn for 'the development of high resolution electron spectroscopy' (1981).

- N. Bloembergen and A. L. Schawlow for 'the development of laser spectroscopy' (1981).
- E. Ruska for 'the design of first electron microscope' (1986).
- G. Binnig and H. Rohrer for 'the design of the scanning tunneling microscope' (1986).
- G. Charpak for 'the invention and development of particle detector, in particular the multiwire proportional counter' (1992).
- B. N. Brockhouse for 'the development of neutron spectroscopy' with special reference to constant-*Q* method (1994).
- C. G. Shull for 'the development of neutron diffraction technique' (1994).
- S. Chu, C. Cohen-Tannouji and W. D. Phillips 'for the development of methods to cool and trap atoms with laser light' (1997).
- J. L. Hall and T. W. Haensch for 'laser based precision spectroscopy' (2005).
- S. Haroche and D. J. Wineland for 'ground breaking experimental methods that enable measuring and manipulation of individual quantum systems' (2012).
- I. Akasaki, H. Amano and S. Nakamura for 'the invention of efficient blue LED' (2014).

The award has gone to scientists for developing experimental methods and devices with such monotonous regularity that it hardly seems necessary to cite more examples.

If we wish to innovate and invent at the frontline, we need to build this culture into our system of education. Our students at every level should be mandated to have hands-down experience with simple experiments involving rudimentary construction, gradually increasing in complexity, which, at the tertiary education level, should grow to project work involving some construction of apparatus. This need not involve great expenditure. I learnt my soldering and plating from my 'kalaiwala', who used to do plating for our brass vessels. This helped me in building a methane liquifaction system for my Ph D. In 1930s, when no research fund was available, M Sc students at the Banaras Hindu University, Varanasi built and investigated Geiger–Mueller counters[5] and devised optical silvering methods (for astronomical telescopes) which were of a standard prescribed by the National Bureau of Standards of USA and better than the then prescribed method[6]. Today we have a National Policy for innovation. We need to embed it into our education system. This, of course, requires teachers and guides who themselves think of innovative methods of imparting knowledge. Such teachers need special recognition by the Central and State Governments and our Academies. Recommendations to Governments on innovation, instrumentation and invention will bear fruit only when our scientific community starts respecting and duly recognizing the importance of this type of manpower, rather than overemphasizing paper publication and impact factor. In my opinion such appreciation is lacking. Our senior scientist K. R. Ramanathan, in an IPA meeting discussing ways of attracting students to science, said that this will happen only when society starts respecting scientists.

1. Singh, R., *Curr. Sci.*, 2009. **96**, 419–422.
2. Venkataraman, G., *A Journey into Light*, Indian Academy of Sciences, Bengaluru, 1988, p. 208.
3. Venkataraman, G., *Bhabha and his Magnificent Obsession*, Universities Press, Hyderabad, 1944.
4. Dasannacharya, B. A. *et al.*, *Neutron Scattering in the Nineties*, IAEA, Vienna, 1885, p. 443.
5. Dasannacharya, B. and Rao, G. S., *Nature*, 1936, **138**, 289; Dasannacharya, B. and Krishna Moorthy, T. S., *Philos. Mag., Ser. 7*, 1937, **xxiii**, 609; Dasannacharya, B. and Seth, A. C., *Philos. Mag., Ser. 7*, 1939, **xxv**, 249.
6. *Scientific American*, 1940, **163**, 33 (An appreciation of a paper by Dasannacharya, B. and Seth, A. C., in *Philos. Mag. Ser. 7*, 1938, **xxvi**, 953.

B. A. Dasannacharya lives at #4, Beach Resort CHS, Sector 10A, Plot 1, Vashi, Navi Mumbai 400 703, India.
e-mail: adasannacharya@gmail.com

Cultivation of *Saussurea costus* cannot be treated as 'artificially propagated'

Chandra P. Kuniyal, Dharmendra S. Rawat and Rakesh C. Sundriyal

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) has resolved that 'the species of fauna and flora that are or may be affected by trade should be included in the appendix I (ref. 1). Appendix I includes the species threatened with extinction and only in exceptional circumstances, trade in specimens of these species is permitted[1]. The fifth and sixth points of a prescribed application format by the Government of India (based on which the trade of particular species – alive or its products – may be permitted) for 'issue of documentation regarding export/import/re-export of CITES listed flora and fauna' asks for (i) source of procurement (collected from wild/bred in captivity/artificially propagated), LPC (legal procurement certificate) number and (ii) country in which the specimen was taken from wild/bred in captivity/artificially propagated[2].

Saussurea costus (Falc.) Lipsch., also known by several other synonyms in the scientific literature like *Saussurea lappa* (Decne) Sch. Bip., *Aplotaxis lappa* Decne., *Aucklandia costus* Falc., *Aucklandia lappa* Decne., *Theodorea costus* Kuntze (Sanskrit – Kushtha, Kashmiri – Postkhi, Tibetan – Puchuk or Putchok, Hindi – Kuth or Kooth, and English and trade name – Costus, family Asteraceae), is an ancient medicinal herb. Its roots are used in ayurvedic formulations, cosmetics and various other herbal formulations[3]. *S. costus* is listed in appendix I of CITES[4] and specified plants in the Schedule VI of the Wildlife (Protection)