Rochechouart craters indicate formation in late Triassic palaeomagnetic dipolar field of normal polarity at the Manicouagan but reverse polarity at Rochechouart[8]. This feature revealed by the magnetic minerals at the two sites, according to Kent, indicates an incidence of geomagnetic reversal which implies that the two impact events must have been separated at least by a few thousand years it takes for geomagnetic polarity reversal to take place; and such reversals during the Triassic times have been known to occur about twice per million years[9]. Spray, however, is not convinced by the palaeomagnetic data and feels that the samples for the magnetic studies were drawn from the crystalline rock material and not from the glassy melt[10]. In the former, the magnetic mineral phase develops only when the mineral passes through the Curie point (the temperature at which iron minerals assume magnetic order), a point that an ~200–500 m thick body like Manicouagan superheated melt can attain only after tens of thousand years of slow cooling to generate crystalline structure and magnetic order. Consequently, Spray claims that although both Manicouagan and Rochechouart could have formed within a few hours of each other, the resulting impact generated rocks would have reached Curie points at times sufficiently different to allow for a natural geomagnetic reversal to have taken place, accounting for different polarities of these impact structures[10].

Planetary scientists also disbelieve that earth's weak gravity could have captured a comet or asteroid and disrupted it in the manner Jupiter's strong gravity did (Jupiter–Earth difference in mass being over 1–300) when it broke SL9 into several fragments and later drew them on to its surface[11]. An alternate explanation put forward by some envisages that a comet or asteroid is first fragmented during a grazing impact over the earth's atmosphere and subsequently captured in the earth's orbit only to be pulled down on to its surface during its next pass-by[12,13]. However, break-up or fragmentation processes, theorists feel, usually bring about crater clusters and not linear chains, except occasionally as secondaries to large impact events. Though possibilities for multiple impacts over primeval earth do exist, their unlikely survival overcoming destructive geological processes and remaining exposed uncovered by younger formations during the intervening long time span, poses difficulties in their recognition today. Secondly, the critical test for the synchronicity of craters, no doubt, requires that they exhibit similar ages, but whether the narrow precision required for this purpose, overcoming the uncertainties inherent in the isotopic dating technique for attaining this high precision is achievable, is a big question. It appears that, for the present, as Spray *et al.* have expressed, spatial alignment of craters remains a reasonable test for advancing synchronous origin, unless disproved by other studies.

1. Ash, R. D., Knott, S. F. and Turner, G., *Nature*, 1996, **380**, 57–59.
2. Ocampo, A. C. and Pope, K. O., *Lunar Planet. Sci. Conf.*, 1996, **XXVII**, 977–978.
3. Rampino, M. R. and Volk, T., *Geophys. Res. Lett.*, 1996, **23**, 49–52.
4. Sankaran, A. V., *Curr. Sci.*, 1997, **72**, 163–164.
5. Spray, J. G., Kelley, S. P. and Rowley, D. B., *Nature*, 1998, **382**, 171–173.
6. Luczaj, J., *Geology*, 1998, **26**, 295–298.
7. Grieve, R. A. F., Rupert, J., Smith, J. and Therriault, A., *GSA Today*, 1995, **5**, 189–196.
8. Kent, D. V., *Nature*, 1998, **395**, 126.
9. Kent, D. V., Olsen, P. E., White and W. K. J., *J. Geophys. Res.*, 1995, **100**, 14965–14978.
10. Spray, J. G., *Nature*, 1998, **395**, 126.
11. Melosh, H. J., *Nature*, 1998, **394**, 221–223.
12. Bottke, W. F., Richardson, D. C. and Love, S. G., *Icarus*, 1987, **126**, 470–474.
13. Love, S. G., Bottke, W. F. and Richardson, D. C., *Lunar Planet. Sci. Conf.*, 1997, **XXVIII**, 837–838.

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COMMENTARY

Why, in the present day world, the difficult is easy and the easy almost impossible?*

Yash Pal

Without being too complacent about what scientists in Space, Atomic energy, Defence and Agriculture have been able to do during last few decades, one will have to agree that it is substantial and would do credit to any industrial society of the last few decades of this century. Nonetheless one will have to confess that India has come nowhere close to what we had dreamed of at the time of our Independence. When I say 'we' I mean people my age who had started working soon after the country became independent. Half our population was never in school. The country has suffered serious environmental degradation, our towns and streets are filthy, many do not have safe drinking water, sanitation facilities are almost non-existent in much of the country, regional and religious disputes and also those based on language and caste have become more vitriolic, crime has increased and population growth has not been checked in many parts of the country.

What I have said about our country is in some measure true of the whole globe. Without going into the state of affairs in many parts of Asia and Africa, it is hard for me to reconcile with the fact that people who went to the moon decades ago, those who have been involved in some of the greatest scientific and technological adventures and accomplishments of this era, belong to the same species who would kill off hundreds of innocent

*Based on a lecture given on the 26th anniversary of ISAC.

persons because some mad men killed half a dozen of their countrymen. Perhaps we should not be surprised because it is the same species which tried to bomb Vietnam out of existence, and who have prevented a mid-eastern country from giving a normal life to its children because it is believed to hide weapons of mass destruction in the palaces of its President – the same kind of weapons they themselves have and produce in abundance. Why in this age of technological exuberance, in this age of plenty, in this day and age where no one should sleep hungry, do we have the same problems we have had all through human history – in fact have them in a far more virulent form? I know the kind of innovation, deep thought, application, dreaming, and creativity that goes into doing great science or inventing amazing new technology. Why is all that absent when we address problems which could be well addressed by workers, farmers, grandmothers and children, given some concern and empathy?

Has our technology taken us away from empathy, except when it is parochial? In any society, the number of people who entangle with the deep and challenging problems of science and technology is minuscule. Also these people are so intensively engaged with their own challenges, that their interaction with mundane issues of society is at best only profes-sional. Such people prefer to remain passive when questions of ethics and morality of certain initiatives need to be assessed. Sometimes, steeped in the arrogance of our science, learning and technological capabilities, we tend to forget that most of the innovations and modes of behaviour, as also our cultural riches, spring from the anonymous creators in society. These anonymous actors feed us, provide repair services, create beautiful pieces of art and artifacts, also music, songs and dance, humour, even literature. Indeed, India is India because of what millions of these anonymous contributors have given from times immemorial. The authors we assign to the beautiful things of the past, as also useful things such as *ayurveda*, were not the sole creators, but mostly collators, of what had already been discovered by people at large. This probably also applies to elements of our great epics and philosophical thought. I believe this explains why the ideas could spread so fast across the length and breadth of this vast country. Seeds of these ideas were already present in the soil.

It seems to me that this tradition of working together with folk creativity and wisdom was broken in our land, when we set out to build our education and science institutions. We thought what the country needed were ideas and creations grown in hot houses, rather insulated from the society at large. Our syllabi and curricula gained their respectability from their similarity to those of excellent institutions abroad, or the elite centers within our own country. Intimacies and specificities were thrown out. By and large we wanted to produce and disseminate distilled wisdom, which seldom found receptors in the social organism around. Also these institutions themselves did not develop any receptors for the signals from society. This might be the reason that our science and technology have remained rather barren. That may also be the reason that millions of people in the country have considered schooling as something which alienates; it usually decouples people from the life, learning and environment around them. This is not much of a handicap if you want to build a satellite or become a clerk, but it is if you want to be designing things and systems which must have a conflict-free and easy relationship with your society.

I have a feeling that we recognized this quite sometime ago in our management institutions when we started lauding the importance of entrepreneurs. An entrepreneur must necessarily engage with the target environment. A space technologist can be an entrepreneur, but the other way around is rather difficult. This asymmetry might be significant, but I will desist from enlarging this discussion in this talk, except to say that even when scientists and technologists become activists, they go out like evangelists to 'popularize' science – most often to impress and not to explain. They seldom go out to acquire fresh ways of thinking, to learn about the constraints and advantages in different settings and, perhaps most importantly, to develop an empathetic relationship with society. This, perhaps, is the main reason why the 'easy' remains most difficult. The problems of the 'easy' do not lie in any hot house.

Let me give you a few examples of grassroot initiative which, to my knowledge, have not attracted the attention of the establishment scientists because they are considered too ordinary and may not be approved as respectable topics for M Phil or Ph D dissertations.

About three years ago, a farmer in Punjab looked at his diesel pump sitting idle in his field, because it had already done its four hours of duty for watering his field. He had a friendly relation with his pump. It was dependable. If it went wrong, he could himself overhaul it; even his ten year old child could coax it into life when it was being difficult. Could its diesel engine be used for driving the wheels of a cart which he was sure he could build, using discarded parts from army jeeps lying in a junk yard? This thought might have occurred to many others, but this farmer decided to test it. So he built himself a vehicle, a wooden cart, with four tyred wheels, springs and shock absorbers, gear box, clutch, transmission system, radiator, steering wheel – the works. The coupling was provided with a couple of V-belts. He ended up with a vehicle costing him about 40,000 rupees. It could carry twenty people, even his buffalo, could run at 40 km/hr and was cheap to run and maintain. If he did not feel like investing in a new engine, he could drive it to his field and couple it to his pump. Asked to give a name to his contraption, he called it *Maruta*, the male of Maruti! Soon other farmers got into the act, some of them became specialists, and the name which stuck was *Jugaad*, meaning junk.

In spite of the fact that the road transport authority has prohibited these vehicles from the main roads, their number has increased; they have spread to the neighbouring states of Haryana and Rajasthan. Even the prices have come down. The vehicles are being used as taxis in rural areas. I have talked with some owners of these vehicles in Rajasthan. They feel good about it. They know it completely and can refurbish it, give it their own personality. I can understand how the rule-bound road transport authorities would be alarmed at their proliferation, though no one has proved that they are less safe than tractor trailers. No one has advertised these vehicles, but their use has spread. There must be something which matches the means and requirements of the rural community. As far as I know no engineering college has made *Jugaad* as a part of their practical

project, in spite of my exhortations during the last two years. Good engineers could find ways of improving it, increasing its efficiency and safety. When I mentioned it to a leading industrialist in the business of manufacturing motorized vehicles his only reaction was that it should not be allowed on the road. I have asked the schools of communication to study how and why this innovation has spread, without the aid of advertising and sales promotion, but so far I have not found any enthusiastic takers. The questions are not related to the interests of the modern and the middle class, nor do they lie in the mainstream patterns of discourse in these disciplines. If even the lowly farmer can do it on his own, surely it cannot be modern enough to demand the attention of the elite in business, science or engineering. What right do people have to decide on their own what is good for them and, horror of horrors, even to go ahead to design, build and use it on their own, without taking our permission? Such innovations are illegal if done in India. It would be another matter if they had already surfaced in China or Israel, if not in one of the western countries.

Three years ago, I along with my colleagues on a committee to examine the parameters of technical education for the real India, visited a Krishi Vigyan Kendra near Patiala. This was an impressive place, engaged in transferring the agricultural know-how from an agricultural university to the farmers in the area. The centre had many associated activities and it was obvious that it was performing a very useful function. We already knew that the farmers in the area took four crops a year and their fields indicated that they already knew a great deal about productive farming. Therefore I was tempted to ask the extension scientists whether they ever received new ideas from the farmers themselves, to be fed back to the university. Their reply to this was an emphatic yes. I requested the scientist to give us an example. The story he narrated went something like this: just the other day one of the regular visitors to the centre came and announced that in addition to the four crops he was already taking he had also planted sun-flower. The scientists were annoyed with his apparent stupidity, because at that particular time the birds attracted to this crop would also devastate his grain fields. The farmer smiled and replied: do you think I am such a fool that I did not worry about this danger? I worried, but I also did some experiments. As a result I have not only planted sun-flower, but I have also started keeping honey bees. The bees also go to the sunflower field and this keeps the birds away. It was not clear whether the bees frightened the birds or provided an alternative meal for them, but the net result was that in addition to his normal four crops, he also had sun-flower and, another bonus, lots of honey. I wonder whether such an innovation could have been suggested by a university or a laboratory scientist. I doubt if this farmer would be ever given an INSA or an ISCA award, leave aside an M Phil or a Ph D?

While I am tempted to go on with these stories I will desist. For several years now I have been sporadically involved with a people's science movement. It started when, even while I was chairman of the UGC, a broad discussion was started on a proposal that for a year or so we might consider moving all education of colleges and universities out into the countryside to engage with society in the raw, to learn, to teach, to reflect and to come back with greater empathy, and better connection and more traffic across the walls of academia. Out of these discussions arose the concept of 'Mass Action for National Regeneration', (MANAR). This was an effort to rectify the separation between those who have acquired reasonable knowledge in our institutions, from the ground realities and concerns of society. Some of them perform fairly well in circumstances similar to those which they obtain abroad or within the confines of their laboratories and organizations. In order to work effectively in the big wide world in their immediate neighbourhood, they would like the society to change to accommodate the solutions they can provide; they forget that changing society is also their responsibility. And if that is to be done, the international solutions would seldom work. It is ridiculous to say that if the expert solutions do not work it is the fault of society. And if local solutions have to be found then an understanding of social urges, societal problems and local fund of knowledge and wisdom must be accessible. That is why we need to engage with our society in the raw to teach and to learn, to develop understanding, but also to develop the empathy which is lost while becoming inorganic experts within inorganic walls.

Some things have been started, but nothing to write home about. We did have a Jatha involving many individuals. We visited over 50,000 villages, hundreds of meeting seminars were held, roads were built, water supplies were attended to and much else was accomplished. More than anything else a large number of young people began to understand the pathology which has so thoughtlessly divided our country into two: one that is India and the other that is Bharat. After a number of such sporadic activities one problem began to appear at the base of all others. I personally became acutely aware of it while working on the committee to examine the question related to the burden of the school bag.

In a strange sense the central problems of India all originate with the problem of the school bag. It is not that our children learn too much. We try teaching too much which is at best memorized. Understanding is seldom the goal. School is a universe in itself. Knowledge is divided into two distinct categories: one which has currency in school and the other which you get from life. The habit of not operating with the first on the second, and vice versa, is developed early. Indeed these two categories become nearly orthogonal. This is what alienates people from society. That is the reason why so many children drop out of school and those who do not try dropping out of society, at least seceding from that which is India. This tendency persists all through our education. We have little relation with industry on one side and the traditional capabilities and skills on the other. Our good engineers are more comfortable with the world outside than with the conditions within the country. The challenges within seem unexciting. Unless we address this problem of alienation, our science and technology will not help in creating an integrated and vibrant India. And we cannot address this problem unless we accept that there cannot be dead uniformity of topics through which we teach. The syllabi, if not the curricula, have to be localized. When we do that there would be chance of tuning into the diversity of the country. We will be more creative and stronger even if not uniform. Uniformity is an ill we have tried inculcating with disastrous consequences. The only justification for

demanding uniformity is to simplify the process of filtering we call examinations. They used to be for a few mundane jobs, previously of clerks and now not much different. Examinations have become the aim, the purpose, not the means of ensuring good learning, not even for finding the right people for the right functions.

If one allows oneself to be carried along by this line of thinking one can almost persuade oneself that the cause of many of our inadequacies lies at the bottom of our education system. That should be something easy to correct. But, as I posed right in the beginning of this presentation, just because it is so easy it becomes almost impossible in our society. Perhaps we should make it a bit difficult and then it would happen. We just have to turn that switch.

So the current engagement of many of my friends and colleagues, most of them of the Jatha and the MANAR vintage is the Lokshala programme, where our slogan is 'From Pathshala to Lokshala'. I invite all of you to participate. You may think that we are tilting at the wind mills. I personally do not think that is such a mad way of living, not in the present day world.

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Biodiversity, conservation and evolution of plants

D. D. Pant

People dealing with more exact sciences like physics and chemistry feel somewhat uncomfortable with biology. A reason for this could lie in the undefinability of life. It has to be stated with all emphasis, which I can muster, that among all the branches of science, biology is the only branch that cannot define the object of its studies. There is no strict definition of life and even all its exact experiments are performed on dead cells or tissues.

Among all the branches of biology, biochemistry and biophysics approach the more exact sciences wherein experiments can be conducted and repeated to confirm their conclusions. However, there are branches like taxonomy, morphology and palaeobiology that are mainly descriptive and even historical, relying more on observations, descriptions, and classifications of the diversity of form and structure of the organisms under study. It is, at the same time, necessary to add that even among the 'hard' physical sciences, astronomy too is observational and non-experimental. Compared to the diversity of chemical elements, which number about 10^8 or more, the diversity of form and structure in plants and animals is infinite and the exact numbers of genera and species cannot be accurately stated. Furthermore, between the genera and species of plants and animals, infinite varieties exist which tend to intergrade them and I can only repeat a statement, which I made in 1954 (ref. 1), while classifying spores and pollen grains that it is difficult to draw boundary lines in the fine gradations of Nature: Classifications are after all, all artificial.

However, underlying this biodiveristy of our undefinable objective called 'Life' is the process of diversification: evolution. This process has been going on for nearly 4000 million years from now when life arose on our earth, and I must emphasize that it is still going on. You have only to look around and find for yourselves numerous examples of the process continuing among our plants and animals. Take, for example, the use of DDT and the new antimalarial drugs for the eradication of *Anopheles* mosquitoes and malarial parasites for the control of malarial fever. Very soon thereafter we came to know that the use of DDT and some of the newer drugs being used had given rise to breeds of mosquitoes and malarial parasites which showed resistance to these drugs and the threat of malaria has reappeared. To me this is clearly an example of the continuing diversification of life and shows that plant and animal taxa are in the process of continual change. We must also remember that diversity not only increases but also decreases. This is obvious from the fossil records which show that many plants and animals have indeed become extinct. Some of them like, dodo, of which one species *Raphus cucullatus* was living up to 1680 in Mauritius but thereafter it became extinct. Another species *R. opterornis* lived in the island of Reunion until the late 18th century. This flightless bird was killed by man for food and thus became completely extinct[2].

Before I go on further, I must say that the present century has witnessed two great advances in science, both concerned with the fission of nucleus.

One of these advances led to the fission of the atomic nucleus by physicists, resulting in generation of atomic power. The use of this power caused unparalleled devastation of two Japanese cities of Hiroshima and Nagasaki, and I should add that we are still experiencing its after effects. A second outcome of the same fission of atomic nucleus has resulted in generation of atomic power for peaceful purposes. It is claimed that this power, in the long run, would be able to replace our fast-depleting sources of energy and irretrievable fossil fuels. But many scientists differ, and have already cautioned us about the hazards of ionizing radiations resulting from atomic wastes, like plutonium, whose radioactivity takes a long time to decay before it attains safer levels.

The second great advance was made in the field of biology and once again it involved the fission of the cell nucleus which resulted in our coming to know the genetic code of the DNA molecule, responsible for inheritance of characters from parents to the progeny. A result of this knowledge has given us the capacity to manipulate the genes in the code by what is called genetic engineering. This can give us the power to create novel forms, species and genera.

Thus far nature and natural factors were manipulating genes due to aberrations or mistakes in the replication of DNA, thereby leading to mutations by factors which were mutagenic. Their mode of action was largely unknown, but now we are learning to manipulate genes. We may thus create new forms at will and thereby enhance or retard the rate of