increase in surface microhardness and wear resistance after laser surface treatment. The technique is relatively recent and promises to possess a large number of applications.

1 Franz Simon, *Plating and Surface Finishing*, November 1994, p 16
2 Pantelis, D, Giannetaki, E, Chryssoulakis, Y and Ponthiaux, P, *Plating and Surface Finishing*, November 1994, p 52

V Lakshminarayanan is in the Raman Research Institute, Bangalore 560 080, India

OPINION

Dynamics of the psychology of the Ph D students and the question of what to do with them

V. Sitaramam

We have a reasonably sized work-force of research scholars in the country, who spend anywhere from 4–8 years in search of a doctorate. Nearly all the research in the country, good, bad or indifferent, is carried out by them. Many go abroad while some remain behind or even return These are the main takers of whatever jobs that are available. Since the time span they spend on an average is nearly the same or more than a professional student does, the suggestion is that we impart some breadth into their programmes This requires a critical view of what is currently going wrong. Useful statistics are hard to come by, though much is known by experience. This note is a plea that we should understand this species, the doctoral student and his/her dynamics (more of the lack of it). Since the overall scenario of science in the country is far less than satisfactory, if not dismal, we need to do something about this critical group of captive students, in our own interest of jobs that need to be managed. Can we actually use it in a more efficient manner? *We have to shift our focus in planning to our average performer rather than to the desirable performer, if our plans and the reality have anything to do with each other*

What to do with higher education and research in India is a point of considerable discussion these days. Is it possible to reduce the problems of higher education to a simpler theme and keep hammering at it in the hope that something useful happens? The Ph D student is the pivot, the focal point, the basic workhorse, the cannon fodder..., or whatever, of the research life in India as elsewhere. The entire higher learning has this milestone, the doctoral degree,

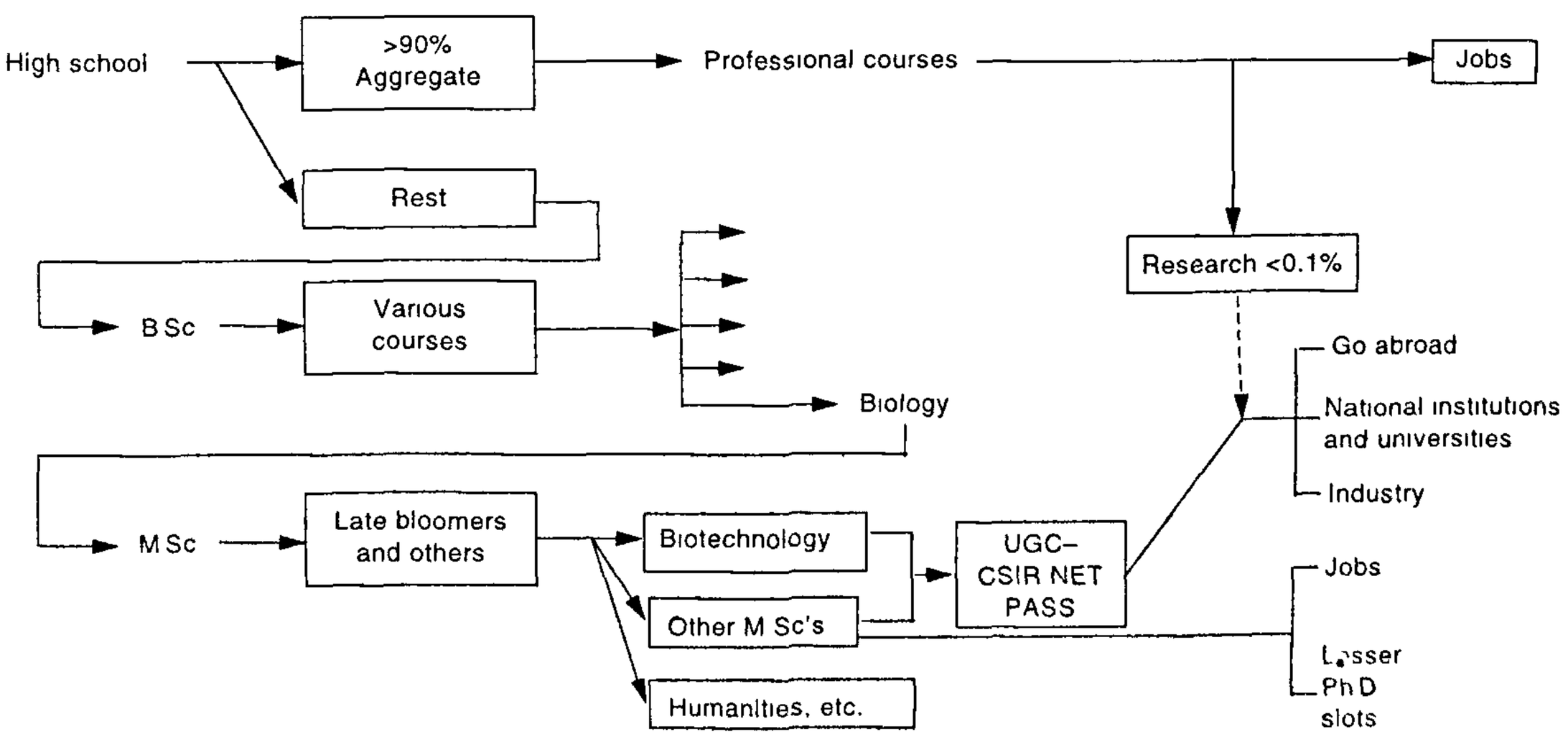

Figure 1. Flowchart of students.

as the determinant The Ph D student and his her psychology seem to matter in all matters of higher learning and hence the choice of the topic.

Who are the scholars?

If we look at the very beginning as the stage gets set, we need to begin with the schools In the child we have the dichotomy, the fantasy (the mind-sets invoke play and non-utility) and the fact (the mind-sets invoke rote, discipline). Schools opt for the latter. When schools do not teach even this, or when what is taught is inadequate for the purpose, coaching classes mushroom, as indeed they have These classes cater to a need that is felt and that is real. There is no point in arguing the merits and demerits of these coaching classes. They serve the purpose of imposing learning that is not inborn. This learning need not be creative. It cannot be. It need not be global. It is only for a specific purpose of a test. It is often argued that school examinations are oriented to cramming by students. No one has prevented the students from wanting to learn and to understand. It is the wisdom of the task-oriented teachers and parents that carefully and systematically eliminates comprehension from the ambit of the children. Children do not *find* questions. They do not even find answers to their questions. They are carefully given as pre-digested bite-size answers which are crisp, clear, unambiguous and would atrophy any thinking[1]. We call that systematic education. Haldane, I believe, remarked a few decades ago that if you take a bright student and teach him three years of systematic botany (sic), you would have killed any chance of that student ever thinking again. We can replace that subject with many others – in fact, any subject given the right level of mediocrity.

It is exactly the same wisdom among the guides that robs the Ph D students of introspection to have doubts about the creativity or purpose of what they do. What we have created in the university system is an uncontrolled, rudderless machinery for Ph D production in the same manner as we have coaching classes for kids. The question is not how to get the best approach to train high-level scientists. The question is what else we can provide such that these students in the collective, professional sense reach the job market more efficiently. In that case, it becomes sensible to try the time-honoured mass methods. Why not more coaching?

This is a drastic view. Let us examine it again. Market forces have always determined the work-force A career in science is not the main attraction for the bright student. The choice is primarily by default Even the definition of a bright student should be carefully considered. Educational psychologists are very discriminating about it. Are we? By and large, the experience is that the marks at the 10 + 2 level decide the 'academic' fate of an individual (Figure 1). Educationists know that our school system, though better standardized perhaps than ever before, is not particularly geared to inculcate original or creative thinking. But then, why do these marks matter so much? One suspects that this has to do more with the social forces that make the students performers rather than the scholastic achievers *per se*. The school system successfully *selects* certain mind-sets that have the stereotype. Those who have not made it to the top at the 10 + 2 level (which is a kind of 'IQ plus grind as grind can be' test) possibly reflect a social conundrum wherein the competitive edge is taken away due to a series of social and non-academic circumstances[3]. It is important to understand that they exist since that is the cross-section from which we draw upon our major Ph D work-force.

There is considerable lamenting that the bright professional students do not opt for research. Professional education, by its very essence, is purposeful with end-points clearly in sight. This very mind-set, carefully inculcated in the best of the institutes as required for professional training, cannot be blamed for being successful!

It does not mean that we should lower the level of our thinking or encourage lesser performance or even justify the existing cult of mediocrity. We simply should strive for additional provisions. Incremental improvement – is it not the in word?

Who goes for research?

The basic message in Figure 1 is simple. Those who perform very well at school level (i.e. 90% and above marks) rarely, if ever, allow themselves to get caught in the net of science. Therefore, we are doing with less than the best (is that true?) available for science. This lack of performance is not only at the student level The national policy is that in the CSIR–UGC NET, the lowest level is a lecturer, i e. one who is not qualified for either CSIR or UGC Once a lecturer, some day a professor[3]. How the recently introduced SET changes the picture is anybody's guess. What is of concern is not the lack of performance, nor the poverty in quality students. What is important is to examine certain mind-sets in our non-professional attitudes that carefully forge these shackles on the minds of the students.

There is no explicit reason why one has to do an M Sc before doing Ph D. In fact, the experience has been that the sooner the student is thrown into the waters, the better would he swim It is the low level of Indian B Sc that argues for an M Sc before Ph D. Similarly, it is the low quality of the M Sc that requires that there be an M Phil. Then more course work during Ph D!

The focus here is, as it should be, on the failing student. The students will fail because any assessment of performance is normative and some cut-off has to be introduced[4]. Therefore, failures *per se* are not a problem since these are normal to any system of assessment. At the Ph D level, *lack* of failures is the problem. We have the Parkinson's fifth (?) law operative: *for every thesis, there exists an examiner of required level of empathy.*

Dynamics of psychology of the research student

The reason for wanting to understand the dynamics is that different attributes like confidence, performance, capacity, etc., do not go together. Let there be a student S in a lab LAB, guided by FM, a faculty member. FM is moderately funded, quite good, and publishes in journals with a reasonable impact. His research problems are fairly set and are of assured Ph D quality. He may be demanding or not demanding. We may straightaway dismiss the three-way chart, a static view, consisting of three classes of students, guides and problems: excellent, average, bad, i.e. 27 combinations[5]! Neither the guide nor the student wishes to be classified this way and each finds himself/herself exceptional in some way.

Let us consider only the good cases. When the student joins, he does so with the best foot forward on the wavelength

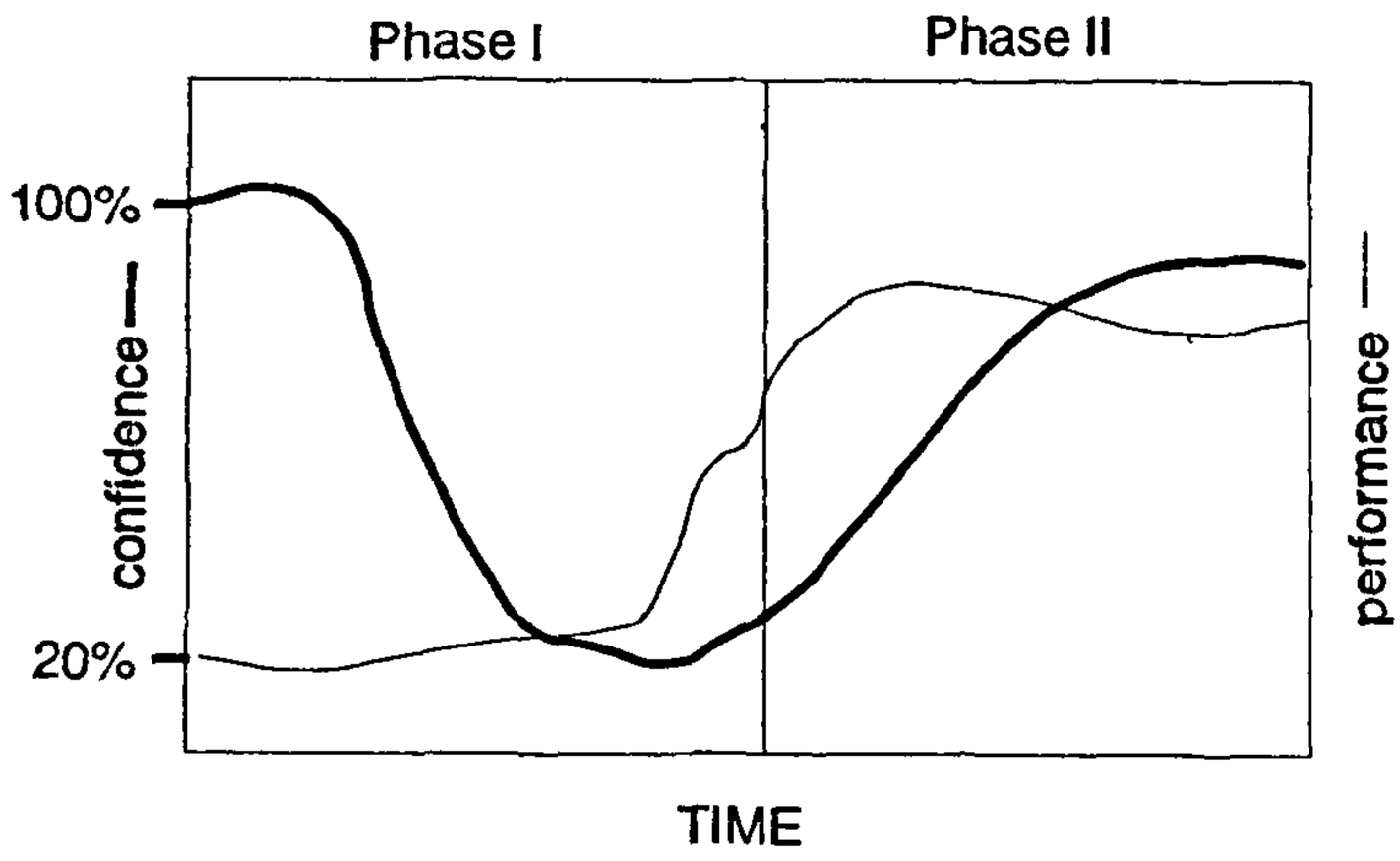

Figure 2. Dynamics of the psychology of a doctoral student.

that 'the guide is tolerable and even a nice chap. The problems are sort of okay which can be set right once we get the ball rolling, or once we finish the survey and discussions'. There are three possible outcomes within the first two crucial years:

O1 The student takes off readily on a ready problem and gets a paper or two in that time, the thesis end is in sight and the guide smiles at him every morning and *ad nauseam*.

O2. The student fares miserably and does not get to the heart of the problem and there are lots of difficulties. The guide definitely does not smile.

O3 Nothing really happens. There seem to be some results which are promising but really require more work. The student has some difficulties and anyway the previous student's thesis/ publication must be completed before we can come to grips with this problem. The guide smiles, but vacantly or in a preoccupied sort of way.

The superficial phenomena are underlined by a series of internal events depicted in Figure 2. In all probability, when the student has joined, his performance is low and his confidence is high. If the desired outcome is a self-assured student with a realistic view of oneself, then O1 and O2 are both undesirable O1 robs him of the competitive edge to improve himself and O2 is a no-win game We shall pursue O3 a little further What is happening is that while the confidence is eroding, the performance is actually improving such that a conceited individual (what else do you call a fellow whose confidence far outstrips his performance!) slows down and becomes introspective. He is blissfully ignorant that his own performance is actually improving since he meets failures This student now reaches stage 2 in 2–3 years. Nothing spectacular, but he achieves first one or two major results. Elation is not in order since others have done it sooner. The only silver lining is that it is a hard-won battle. The guide is not overtly enthusiastic and has not given up either. Now the time for the second wind. The confidence increases with each successful piece of work till either it meets the performance (self-assured individual), exceeds (a pain) or is a little less (nice chap really). The time has come to submit the thesis. At this point, as they say, the lab and the guide are cold coffee or yesterday's newspaper Move yes, but move with what attitudes, skills and capacities?

What constitutes Ph D training

Specific views are stated with regard to research training. We need to examine each of the scenarios to see how well they fit in.

1. *Top of the ladder scenario* Here we visualize the very best of the students exposed to the very best of the institutes of faculty to work on the very best of the problems; of course, to get the very best, e g. the Nobel prizes Facts are not encouraging. One offshoot of this argument for search for excellence is that we have a plethora of programmes that cater to the so-called very top few. Top guns can be only a few. We have scientific exchange programmes, interuniversity liaisons, international science fares of various kinds, even science cities and NRI universities contemplated.

2 *Ill-fated match scenario.* When it is clear that the highest-ranking students opt for careers based on market forces, this second scenario is proven to be more common than one publicly admits. One gets a real feel for this by attending the national committees for research fellows and associates and interviews and project review committees. Ill-supervised efforts bring forth large numbers of less than ill-qualified young researchers These create their own market and to suit their needs pay-and-publish journals have mushroomed The entire system hangs on the human susceptibility of avoiding unpleasant decisions.

3 *The bulldog scenario* is the highly unromantic approach with marked tenacity. Performance is often limited by lack of tenacity and clarity of purpose than brilliance. In this grey land, yardsticks of performance are harder to define. This requires only will.

Delusions *vis-à-vis* visions

All these scenarios essentially point out that we have every reason to believe that we have a system without introspection that continuously dilutes focus and performance. Part of the problem is in the structure of science itself, since dreams are the stuff that the best science is made of. Science as a way of life does not distinguish readily delusions from visions. Any person can rightly maintain that he or she has not the right problem/environment/ guidance/inspiration or whatever and if only the situation were different, Nobel prizes would have been there simply for the asking

In order to think of the job-worthiness of our Ph D students, the *top of the ladder* scenario must go. The cutting edge approach to science in this country has been less than successful It only created alienation in a country that is yet to find its collective scientific roots. Removed of all embellishments and romantic notions, science is as

Table 1. A list of decidedly not advanced but merely useful workshops of use to doctoral students

Future prospects	Possible courses to go through during Ph D
Teaching-cum-research posts'	1. Workshops on grant writing 2 Workshops on teaching methods 3. Workshops on manual writing 4. Workshops on grading students 5. Workshops on computer programming/ statistics/quality control
Teaching posts	1. Workshops on teaching methods 2. Workshops on manual writing 3. Workshops on grading students 4 Workshops on encapsulated B Ed and M Ed type of courses
Industrial jobs	1. Workshops on sales and marketing 2. Workshops on quality control 3. Workshops on management skills 4. Workshops on data management

humdrum an activity as any other, no more or no less inspiring, much having to do with daily chores, barring an occasional grace bestowed upon as an inspired idea that actually works!

What is the purpose of Ph D training?

We next ask the question, what are the Ph Ds for? Top dogs cannot be bred or taught. They simply emerge Obviously, not all students will become great researchers The most rock-bottom requirement is that they should be fit for some job, in the same sense as an IIT graduate is found fit for most jobs, including industrial management, banking and even IAS The problem is that the Ph Ds have a smaller market, being older and more specialized subjectwise The Ph Ds simply should decrease the odds of finding a suitable person for occupations such as research and teaching as a class compared to selection from the lay public If the Ph D does the job better with verve and imagination, that is a bonus

A recent write-up in *Nature* talked about the unusual job markets for biologists in the Wall Street. A good number of biologists, particularly in biophysics and so on, use techniques in data analysis, time series, chaotic cycles and so on, to see and benefit by discerning some method in the madness of stocks and shares[6]. So why not see what jobs would be available for Ph Ds and ensure some programmes that make them fit into these better? Let me list a few possibilities and some remedial courses and programmes that would make them better than the ordinary (Table 1). These can be offered as workshops or summer schools or refresher courses (in lieu of refresher courses for the faculty in colleges through academic staff colleges) and a couple of summers spent by each scholar will at least ensure some marginal improvement in future.

Finally, where does all this take us? Evaluation of the psychology of individuals tells us but one simple lesson Career options are not often by active choice. Regardless of our training and jobs, we attempt to do what we wanted in the first place, or at least not do what we got instead trained for. Much of the higher learning is imposed rather than chosen in this environment of restricted opportunities The options of students mostly do not coincide with the choices they want, including higher education itself. Some time soon, the reality dawns and we settle for what we have. Here shopping helps Five years of research and no future in sight will impose some thinking on the students. Can we help there? We must have our Ph Ds with more skills than whatever work they have done, if they have to have job potential. Job potential does not mean the ability to find jobs. Job potential means the ability to execute them, given the jobs. Majority of the jobs, including teaching, do not require the best minds but these require, hopefully, committed minds but with *assured minimum capabilities*. There must be some professional skills imparted, the younger the better. These students will eventually fill the posts available. It is better to take them on when they still have a chance to learn If we need programmes to help make some kind of professionals (in the positive sense) of our Ph Ds, we need to take them as our starting point for innovation.

Notes

1 In a recent meeting on Biochemical Education at Gulburga, an M Sc student clearly outlined her view of what constitutes an ideal teacher Two points reigned supreme Clarity of what is taught and total lack of ambiguity and eminently good manners such that no feelings are, however slightly, hurt The difference between a teacher and a nanny got very blurred

2 In my biotechnology class, majority come from nuclear families where both parents are likely to be earning, English is the common language spoken largely at home and the grandparents are likely to be living separately and the mean income exceeds Rs 1–1 4 lakhs per year The students themselves tend to be of narrow interests and tend to be isolationists compared to professional students Majority have so far opted for Ph D if they made it past the CSIR–UGC NET Their mean 10 + 2 marks are much less than 90% What is striking is that the students in other disciplines uniformly exhibit much less will to exert themselves while the intelligence level shows wide variation What is striking about the biotech students is that there is a large variation in their will to put in effort though their intelligence level is nearly the same

3 Many universities in the country have abolished the class distinctions such that even a school teacher is referred to as a professor (there was a movie to that effect in Hindi long ago!)

4 The cut-off is statistical though always interpreted and used as a divine injunction Or else, it is difficult to understand the enormous drive for scoring in exams Whatever be the complaints about the system, viable alternatives applicable on a mass scale are yet to be projected Small-scale intensive alternatives were always individual-based and suffer from the lack of long-term survival and generality for mass application in practicable terms

5 Definite correlations exist among the guides, problems, students and places to the extent that one may remark that ducks go with ducks and swans go with swans In a country where there is massive confusion between mass education and mass higher education, we have to contend with a number of realities which are too obvious to enumerate

6 Patent clerks who dabbled in physics, speaking conversely, also have been tolerably successful

7 To go abroad for postdoctoral work: 1. Workshops on indology, literature, arts, music – anything to learn to cherish, to pass the idle moments and as a salve to bruised egos when treated as second-class citizens or as mere slaves 2. Workshops on martial arts to prevent getting mugged

V. Sitaramam is in the Department of Biotechnology, University of Poona, Pune 411 007, India

SCIENTIFIC CORRESPONDENCE

Antioxidants: Helpful or harmful?

In the light of the popular hypothesis that consumption of dietary antioxidants or supplementation of antioxidants protects against degenerative diseases of aging such as cancer, cardiovascular disease, immune system decline, brain dysfunction, cataract, etc., over the past few years, it has become a tenet that taking high doses of antioxidant vitamins like vitamin C, E or β-carotene may protect against a variety of diseases. As a result, 'antioxidant' has become the nutrition buzzword for 1994 (ref. 1) In the light of this popular trend towards antioxidants, many prevention experts nowadays have to struggle to make sense of more recent startling findings that supplements of antioxidants can be harmful[2]. The controversy after the publication of these findings of a large-scale Finnish study on vitamin E and β-carotene is difficult to understand Instead of protecting against cancer, results of this study have clearly shown that supplements of antioxidant β-carotene markedly increased the incidence of lung cancer among heavy smokers in Finland. Total mortality was also reported to be higher among those who took β-carotene. Clearly, the public is confused about the antioxidant vitamins and their benefits. Both advocates and manufacturers of vitamin supplements found these results inconsistent with their own beliefs. But the fact is that these results come from a large, randomized clinical trial – the gold standard test of medical intervention.

A similar type of controversy also exists about the supplementation of vitamin C and E[3,4]. However, so far, the beneficial effects of β-carotene, a precursor of vitamin A, were never questioned. In some circumstances, vitamin E supplementation, instead of protecting against heart attack, may promote excessive bleeding and can be harmful[3]. Large doses of vitamin E enhance immune activity and thus may promote progression of immune and autoimmune diseases (e.g. asthma, food allergy, diabetes, rheumatoid arthritis, multiple sclerosis and lupus)[4]. Large doses of vitamin C can promote kidney stones[3]. Vitamin C is especially dangerous in the presence of high body iron, which promotes the formation of harmful free radicals[5].

To prove the usefulness of antioxidant supplements, a number of intervention studies have already been completed and several others are still underway. A large-scale study conducted in 1993 on a group of nearly 30,000 Chinese with a high frequency of stomach and oesophageal cancer has provided strong evidence to show that 'antioxidant' supplements may protect against cancer[6]. This study showed that nutrient deficiencies promote the development of some types of cancers, and correcting these deficiencies can reduce the frequencies of these cancers. It has been known for quite some time that nutrient deficiencies promote cancers. In the Chinese study, intake of 'antioxidant' vitamins A, β-carotene and E was below the minimal daily vitamin requirements to sustain normal metabolism. Raising the intake of these vitamins above the minimum daily requirement eliminated the deficiencies that promoted the cancers. This study clearly indicates and supports the previous notion that supplementation of antioxidants protects against cancer.

The Finnish large-scale study goes against all the available evidence on the beneficial effects of β-carotene. In this study, 29,133 male smokers participated. These subjects were supplemented daily with vitamin E and β-carotene, both or placebo. Contrary to the expectation, neither of the vitamins prevented lung cancer. In fact, lung cancer rates were 18% higher with β-carotene than with placebo, and there were more deaths due to heart disease. All-cause mortality was 8% higher among those who took β-carotene than among those taking placebo. One of the aims of this trial was to test whether β-carotene prevents lung cancer and this viewpoint was based on several studies which did not indicate any harm. Hence, the findings of this trial were totally unexpected.

The difference between the Finnish study and the large-scale Chinese study is that the Chinese study subjects were deficient in the so-called 'antioxidant' vitamins, whereas the Finnish subjects were not deficient in any of these antioxidants. The other question that can be raised is how far one can extrapolate these findings from the Finnish study to people who are not Finnish male smokers as other studies show protection from β-carotene. The only way to find out whether β-carotene is beneficial or harmful is to wait for the results from other large-scale ongoing clinical trials on antioxidant supplementation. But these trials raise a difficult question that, in the light of Finnish results, is it safe to expose thousands of people to large doses of β-carotene?

In order to understand the beneficial and harmful effects of antioxidants, it is necessary to have a close look at the differences between supplementation of antioxidant vitamins and the natural antioxidant vitamins present in fruits and vegetables. The term antioxidants in biology broadly means fighter against harmful free radicals. In fact, these are redox agents, antioxidant under some circumstances and pro-oxidant, producing billions of harmful free radicals, under other circumstances. Antioxidants in physiologic quantities found in natural foods are often fighter against harmful free radicals, whereas antioxidants in pharmacologic quantities found in supplements often produce billions of harmful free radicals

We need to answer the following questions: 'If I eat carrots or drink