both in commercial and non-commercial sectors. For instance, when the ERNET project began it was based primarily on telephone links using low speed modems (300 bps!) when our telecom infrastructure left a lot to be desired. Its success needs no elaboration although critics had not given it much chance of survival. The success of highly reliable commercial data networks in India are other examples.

The telecom facilities available are adequate to initiate the plan presented in my article. Moreover, we have every reason to think that the telecom facilities will improve, given the ambitious plans of the Department of Telecommunications. Although it is possible to find many faults with the telecom sector, those are not what prevents the realization of the plan outlined. It is certainly feasible to translate the plan into reality as an overlay network riding over an existing one such as the ERNET. The initiatives noted in my article show that beginnings are being made and the plan is, indeed, viable.

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OPINION

What can be done with science education in Indian universities? An attempt at a synthesis

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What options are left for the university education in the country?[1] We were somewhat surprised by the extent of correspondence, national and international, at a personal level, a previous paper on education sparked[2]. However factually and inferentially it may be correct, we were told, it tells little as to what is to be done. The dilemma that confronts us is: do we serve God (of quality) or Mammon (of actuality)?

A real question of immediate import came in the way of a challenge recently to us at Pune University as to what can be done for life sciences at the University. Extensive discussions combining perceptions of our students with those of the faculty led us to realize that most plans are improbable and left us with a very few options. We summarize here a feasible blue print for action, within the university structure.

The central premise is that university reforms cannot be imposed and have to come from within. The turbulence of the last two decades forced upon those who manage industry, government or any other organization the realizations: (i) that an organization is as efficient as the human beings that it has; (ii) these human beings need to be constantly motivated. Ideologies, rhetoric and *espirit de corps* no longer substitute 'hard' incentives. (iii) It is crucial that the 'incentive' be perceived as such by the individual for whom it is meant. (iv) No efficient organization can be run with fuzzy, contradictory and poorly communicated goals. What is being done, why and with what results must be clearly communicated both inside the organization and outside. Thus, reforms in the university can come only when a strong, realistic and credible incentive package (by incentives we do not just refer to pay-scales) is in place and when university goals are clearly articulated. There are fundamentally three players in the university system: the students, the faculty and the university administrators. We endeavour to identify, here, what 'incentives' each group actually identifies itself with and what goals each group visualizes for the university[3]. To be effective, it is necessary to systematically pare away platitudes and clichés thinly veiled as idealism filling the university charters and substituting for proper peer pressure in university life. We are therefore grateful to innumerable students, teachers and administrators for candid views regarding what touches them most, and what they, as individuals, 'really' want. We trust that this is not translated here into an unseemingly gross portrayal of the functions and the functionaries of the universities. It is a sign of our times that governments and peoples across the world have had to make their peace with pragmatism. Why not the University?

The students

The students are clear on *all* issues. Whether we agree with their perceptions or not is a different matter. They have come in after their B Sc. It is *clear* to them that what lies ahead of them after their M Sc is a big question mark! They believe that they are the consumers of the university, with the difference that they have no rights. They believe that the degree should be a value-added product and they realize that it is not. Research is not the highest on their agenda. Most prefer some professional training. None get it.

Some amazing views come out of intensive personal discussions. The students seem to perceive the teachers as a community, . . . the professional scientist, the social climber, the socialist, the administerial ham, . . . as those to whom teaching is merely a front to cater to a variety of other activities where the returns are better. The student does not think much of a teacher, as worth emulating. It is not that they do not understand and appreciate the occasional authenticity and teaching from first-hand experience by a committed teacher. But it is non-essential. The students prefer those who teach them something regularly and not expect them to work too hard. By and large, they prefer the teachers who are generous about giving marks.

We have had students (who would not have qualified for an M Sc) return from abroad and tell us that we should really change and that the teaching in this country is shallow and we must find ways to be better focused and more current. The truly amazing aspect of Western science is not how the brilliant perform. What is amazing is that how the ordinary students do much better there. Their system cares. Therefore it caters.

There is some fascination about what the competitive science can offer to the student. The students are not willing to pay any price for it. They believe that the teachers' job is primarily to teach them, with least hassles. They have no fascination to have a self-willed Laureate as far as their teaching goes. There is no need for high brows at all. They prefer that their places of education have good recognition, *not for academic productivity but for academic performance*. They rightly recognize the IITs for their address. They frankly do not understand why *this working model of academic average for the faculty and academic excellence for students* cannot be emulated elsewhere. The students are very clear that they want all that competitive science can offer but they do not want the high rate of elimination that goes with it. This is not the argument of the weaker, but it is *the argument of the better among the students*. Once they are clear that there are greener pastures ahead by way of a research fellowship or even going abroad, nothing should come in the way of spoiling it. This is the essence of the IIT Mantra, *get grades!* Most important aspect here is that good and bad students are not in conflict, once they are in. The pay-offs are identical. The students do however want all that goes with 'professional' grant-winning science . . . state-of-the-art facilities, skills and opportunities . . . but without any price tags. Over 80% of students feel that at the end of it all the University should add value to them *vis-à-vis* their earning capacity. For the academically inclined, they want it to be a good address.

Parents agree. The views of the two generations are in total consonance. There is no generation gap in this country on the educational scene.

The teachers

The university teachers consider that their primary job is to teach[4]. The teachers sense the lack of progress and most of all resent the fact that they have little say in the control of any of the jobs they are supposed to do. University has a series of Boards, senates and syllabus committees, all of which are partisan and non-participatory and non-evolving. In the absence of having a say, the accountability also vanishes. This is not something that the teacher cherishes. Yet a remedy is not forthcoming or any remedy will be far removed from the reality as he/she perceives it.

There is hardly a teacher who thinks that he/she is not fit to teach nor to do research. Some do make claims that their interest, *not their capability*, may not match. Each teacher prefers a ceiling for the standard of education commensurate with his/her academic level or less and *not more*. 90–95% teachers prefer a job of teaching and less than 10% are also professional researchers. The bulk of the teachers consider the researchers with grants etc. as those who are cutting short their own teaching commitments[5]. Programmes like DSA, COSIST are welcome but there is neither accountability for the funds received nor a recognition for the research that made this possible. There is however a fierce loyalty for the material acquisitions that these programmes bring.

Teachers have no animosity towards researchers. Many have had only a partial brush with research during doctoral and postdoctoral phases and research is clearly an avocation of their youth, or even a youthful folly. Creation of knowledge is not an integral component of their perceived academic life. The faculty see themselves and the University as a 'resource base', with no particular commitment to the students other than teaching. 8–10% of the faculty consists of professional scientists whose primary commitment is personal research. These are perceived to be as those that may neither be good teachers nor may they be very caring, by the rest of the community. 90% of the faculty is predominantly a 'teaching faculty' who perceive that grant winning and personal research eat into teaching which *should be* the basic activity of the university. The economic future of the students is not considered relevant to the job since their view is clearly that of a liberal science education.

The administrators

The administrator has a number of images for the university blissfully unmindful of the internal contradictions. Consider these opposing views: a sanctum of deeply thoughtful academicians highly individualistic and highly productive and respected for their contributions *vis-à-vis* a beehive of professional scientists airport-hopping and grant-grabbing with the slick decor of opulent laboratories and advanced centres for nearly every syllable in a subject; a well-oiled corporate machine catering to the business of higher education with smooth contours of information and action flow geared for catalysing the economic uplift in the free market society *vis-à-vis* a relevant, rural-based, non-profit, socially conscious, utopian and Gandhian instrument geared for social change.

At a more pragmatic level, the administrator sees the vast job of just holding together a large structure to deliver, in some coherent manner, degrees and assorted instruments for youngsters in a society as a palpable unquestionable need. There is a hunger for financial independence without the faintest clue how to achieve it. Earning is an anathema since it curtails freedom. Charity, donations and endowments are better. Government grants come under the same category since they are without scrutiny. There is an eye on the corporate money but no stomach for the grind that goes with it. The economic well being of the students is not of concern since education is a sellers' market[6].

Thus the University administrators would overnight like to see the University in many garbs: As a well-oiled corporate structure, a sanctum for distinguished individuals, an economically aggressive partner for industry, a prestigious recipient of valuable charity, etc. The University wants both the dedicated teacher and the professional scientist but is not willing to bear the cost associated with the benefit of each. The University, like the students, wants the fruits of grant-winning research but is unwilling to tackle the change in 'mind-set' of administration, finance and infrastructure required of a research-driven University.

The punch line

The sum total of all these is that any

structure which is self-seeking resists change. This is true for all educational structures in India and abroad. University lives, as they are, are comfortable and the boat should not be rocked. The only acceptable pitch would be even greater comfort. *Higher salaries for teachers; lower tuition fees or to be allowed to keep terms indefinitely, for students; larger government grants with institutional overheads, for administrators,* are sweet thoughts to be encouraged. This is not an Indian syndrome. It is true the world over.

The sensible starting point is, therefore, to identify the dividends for each of the players and evaluate the minimum requirements and assiduously work out a system that ensures dividends without rocking the boat. If it has elements of mass appeal, it is even better since it addresses itself to a task that gathers momentum by public appeal. Universities cannot exist without public appeal. Public appeal begins at home.

What do parents want of their children? Mind-set at home

The parents all over primarily want their children to be comfortable and financially independent as soon as possible[7]. The education level also has a strong social dimension. The gender factor is a major determinant in the enrolment to courses to the extent that the sex ratios are virtually deterministic, boys in quantitative courses and girls in biology and related disciplines[8]. A professional course caters largest to this class of demands. However, since these have a lot of competition, and since the school marks more or less determine the trends, most do not opt for them. Those who just missed them would opt for more avant-garde courses as outlined earlier[9]. The mind-set is however for a professional course.

There is one good reason for wanting to be in a professional course. The goals are clear and daily reinforced. There is not much ambiguity in ones mind in what to do, being a doctor or an engineer or a lawyer. *Professional courses restrict choices while enhancing opportunities. Future is clear. Liberal education enhances choices but restricts opportunities. Future is confounding*. It is really pathetic to see youngsters meandering through liberal education without finding any roots. IITs offer exactly this in the right combination of a sense of belonging and clarity of careers. There is no reason why other places also cannot offer this by careful planning. However, it is too late to catch students after B Sc. It generally takes the age group of 16–21 years if we consider schooling them into a pattern of living and sharing values. Professional courses, including services, consider this the right age for recruitment based on rather sound psycho-social evaluation.

It is clear that a large percentage of students and parents are discontent with University education that does not integrate a notion of value addition for the student. A serious and immediate question facing a contemporary University (and others across the globe) prone to introspection is: How does one avoid degenerating to a vendor of educational services on the one hand or being totally impervious to the aspirations of the students on the other? We have to examine how valid some of the mind-sets are.

Teachers: A major source of mind-sets

As soon as the teacher is asked the question on what to do with education, the responses are virtually Pavlovian: *improve the examination system*. The examinations refer both to entrance and degree awarding. The question for knowledge base immediately calls for *a syllabus revision*. If you are insistent a little more, then *start new courses and even degrees*. Standard formulae abound. These include courses strangely called *honours* courses, one year post-M Sc, one year post-B Sc and so on. The same people will offer different courses. M Phil represents the ultimate (rot) in the educational system. The least important question in a University system is who teaches what.

Consider the situation wherein the same teachers also teach at the undergraduate level. They can more readily impart a higher level training than at the Bachelor level. But they will not like it unless it comes in a more attractive garb. It will take time to sink in the idea that we need not teach the students and they can increasingly learn on their own. This can be done only when we identify various *skills* in science education, segregate them and arrange for a nearly professional way of handling them. If we finish Masters level teaching at B Sc level itself largely, then the students can spend their Masters time learning skills or doing projects and research.

The teachers will have several existential concerns. Foremost is the problem that the government will have different norms for undergraduate and postgraduate teaching in terms of work load requirements. Therefore it is necessary to retain the M Sc title for the degree at any cost. Will the teacher be burdened with a lot of extra teaching in any innovation? In a practical-oriented course of a professional kind, it is the tasks and not the hours alone that matter. However, a relevant change in statutes and careful planning that efficient teaching and not excessive nor suboptimal teaching will take care of these problems, an area in which the university teachers are quite knowledgeable. Above all, the teachers require manpower to initiate academic programmes. The mind-set that there is something called personal research as opposed to departmental work needs drastic revision. The best revision is to force a situation wherein the teachers have to take care of some research/project, not for a month or two but for an year or two of *every* M Sc student.

The doctrine of growth: The powerful mind-set

The next kind of mind-set has to do with compulsion for growth. This is something we must now seriously reconsider in the face of some facts: one fact that pumping money into research has not brought in its wake adequate returns. Secondly, most departments use equipment for decorative purposes and actual work is small[10]. Thirdly, space is a measure of power and not utility and comes under the category, conspicuous consumption. In the coming days of stringency, we must examine this mind-set the most. However, any one who argues for limited growth will be identified with non-progressive forces ever so present on the campus and therefore planned growth is politically more acceptable than limited growth.

Developments are possible and even desirable at the university. It is possible to identify what each department can do. So we have programmes of tissue culture and reforestation for any botany department, industrial waste treatment and sewage in any departments of microbiology, confocal microscopy and imaging

in any department of zoology and more computers and protein sequencing, cloning and bioinformatics in any biotechnology department. Typical projections can be up to Rs 3–4 crores for each department, if asked. Typically any worthwhile department projects about 25% increase in faculty, 80% in built-up area, 40% in supporting staff, 500–8000% increase in funds when asked for a 5–10 year projection. It is worth asking what the departments have as *the major lacunae, material and attitudinal*: 1. No supporting staff; 2. Low support from administration; 3. Inadequate faculty to share the burden; 4. Notional collaborations and no substantive interactions; 5. Departments perceive such expansions as threats and not help; 6. Often floated question: are these to be developed at the cost of actual teaching?; 7. Where are the research scholars/ or the relevant quality work force?

What can these departments do given all this money? Who will do the jobs that the development entails? Any development requires manpower. M Sc students doing projects (provided they are long enough) and those who just finished Ph D waiting to take off and planning to settle down offer the best bets, provided there are programmes to absorb them and put them to work.

Do we need an M Sc? Another mind-set

In UK, debates flourish whether schools are getting too specialized and whether there should be more of specialization only at B Sc. We ask the same question at M Sc and M Phil levels. In the West, M Sc has never been a major force, required for Ph D. M Sc in this country is a sop to regularize an awful B Sc. M Sc and M Phil help postponement of the entry of the students into the potential job market and permit deferring the issue of career decision.

What do students feel about M Sc programme? They feel they can finish a great deal of the topics at B Sc level itself. Faculty generally agree at least in private.

The question of a research University[11]: The other mind-set

The world bank study published in 1994 slams the western model of higher education as being inefficient, relying too heavily on government funding and inappropriate for developing countries. This realization has cost the world bank US $ 5.1 billion! In developed countries, students and parents are expressing discontent with the quality of teaching in research-driven universities. Governments both in the developed and developing countries would like to know just how much of the wealth generated can be genuinely sourced to the universities.

The writing is on the wall: we live in lean times and those who would spend public funds must be more reflective in their proposals and follow the dictates of circumstance or conscience and not 'as an exercise in subsidised self-indulgence'.

The main danger in being pragmatic is that we lose track of larger goals. It is worth reiterating some larger truths. The university must realize that while every model of a university has its costs and benefits, the university of the future must choose its model, communicate it effectively and integrate it into its recruitment policies, administration, etc. A university that identifies the student as a paying consumer to whom it must add economic value at a reasonable cost is fundamentally different from one that is inquiry driven. The academic goals, course content, faculty it attracts, students it attracts, work-ethic and criteria by which it would like itself to be evaluated are all different. Similarly universities that depend on charity, tax-payers' money or choose to earn their own income are targeting very different audiences and must project very different images. One way to enhance simultaneously different possibilities and goals is to have a multi-tiered programme, where students have considerable scope in developing their own combinations in courses and skills.

Can these objectives be translated into a functional programme?

In a professional course, no course teaches a subject. It teaches how to use a subject! That is mastering it! Otherwise we have bachelors who are divorced(!) from the subject as of now.

So let us not teach biochemistry (to stretch a point): Instead, let us teach

- ... how to assemble a spectrophotometer;
- ... how to do an assay;
- ... costing of an assay;
- ... normal limits to values;
- ... quality control of reagents, and
- ... how to write an expensive-looking report.

Let us not teach algae; let us

- ... grow them;
- ... cost the culturing of them, and
- ... come up with a pilot plant.

Skills in science, research, professional courses and industry have a 90% overlap. There are only two operative questions: *Do you understand? Can you do it?* A professional course recognizes none other. Traditionally science teachers are supposed to help young minds regarding the excitement of science and the wonders of it. All kinds of scientists give affidavits of personal motivation and perceptions of the beauty of science since childhood and what made them choose a scientific career. There is a strong streak of evangelism in all this. The professional teachers merely concentrate in getting the students to do a job, better with time. *Science too needs to be done and better with time.* Should we view science as an independent activity or another aspect of professional training? How do we run such a programme? Let us consider an example of a graded learning experience in three courses:

1. A basic lab course in biochemistry using a range of biomedical equipment available as core modules ready for user defined self-assembly. *Objective*: means of measurement are transparent and not locked up in black boxes.
2. The next level would involve an entire exercise in fermentation. A microprocessor-based fermentor (2–5 l) is built up from modules and inexpensive glassware. The final exercise in fermentation will include on-line monitoring of growth, pH nutrients, oxygen, carbon dioxide, etc. *Objectives*: the exercise in building up such a system from simple modules would constantly reinforce the basic skills while providing a tangible (thus motivational) goal for the end of the course. The content would be rich in that it would impart very fundamental principles from a number of disciplines allowing one to transport the word multi-disciplinary from a popular cliché to a real-life working situation.
3. The final course would be the clinical laboratory. A large number of diagnostics would be devised, using and establishing good laboratory practice (GLP), quality

control (QC), etc. *Objectives*: This would . . . (i) further reinforce the principles of enzymology, immunology, microbiology, etc. taught earlier, (ii) impart real-life skills helping the student in finding a job, (iii) exemplify the use of statistical methodology in real-life situations in QC and GLP, (iv) inculcate formal documentation skills.

Students all too often associate documentation with 'blinding, numbing, crushing bureaucracy'. The course would vividly illustrate that without conforming to standard operating procedures, documentation and myriad reports, successful biotechnology is not possible.

Biotechnology: An illustration of the jump between science and technology in skills

Take the example of biotechnology. Biotechnology is small scale in terms of volumes and very labour-intensive, requiring an extremely skilled work force. Basic skills in use of sophisticated instrumentation and techniques are thus central to the economics of biotechnology. Lack of rigorously trained manpower with hands-on experience can destroy a programme as effectively as lack of material resources. These basic skills are essentially the same for a career in industry or in the basic sciences. Can we take a lesson from there and overcome the mind-set that science and industry are different? Can biological sciences or life sciences then bridge this gap between the intellectual frontiers of pure science and the transmission of specific skills for the job market[12]?

There is a broad consensus in the biopharmaceutical industry that what is lacking is the discipline required of drug/pharmaceutical development. Good lab practice, good clinical practice and good manufacturing practice leave researchers cold. Two points are very clear: in biotechnology; business in the absence of scientific rigor is bound to fail. There is, thus, a very definitive *market* for biotechnology education that integrates *scientific rigor* into the curriculum. Secondly, it is equally becoming clear that the principles embodied in GLP, QC, use of rigorously defined 'go' or 'no go' points and formal documentation contribute significantly to both a successful research career and successful biotechnology. These are things not yet dreamt in biotechnology teaching. There is considerable argument for an MBA in biotechnology. Why are we structuring courses that reduce opportunities instead of enhancing them? Biotechnology, or life sciences in general, form but an aspect of management[13].

What then do basic science programmes like the current M Sc lack?

The nub is in that researchers as students must perceive the need for documentation, for QC, for standard operating procedures. The whole range of skills that the student needs after joining the work place should become a part of early education. In Japan, QC is taught starting from middle school. The prevailing mode is that we teach the same stuff at varying dilutions from school to doctoral levels. In fact, if students can absorb much at an earlier age, there is not much for them to do at Masters' stage. They are then free to do things. Projects, development, even educational activities . . . , all these form part of their curriculum.

Thus, it is clear that all basic science departments in a typical university can get together: physics, chemistry, mathematics, statistics, biotechnology, zoology, botany, microbiology and so on. Basically the university runs two streams: the physical sciences programme and the life sciences programme. These between themselves have 30–40% overlap. No course is in isolation and should overlap functionally with at least 4–5 other courses. No course should be without skills. Textbook-based courses themselves should not be more than 30% of the overall structure in the 5-year programme. Practicals, skills, projects, most importantly report writing (not copying journals but documentation in the professional sense with all the other skills like draughtsmanship, computer graphics, photography and so on and plain typing and spread sheet management) will become part of the programme. The last 1.5–2 years will be spent in actual projects, research or developmental. If some 20–30% is made elective (optional) with some 1–10% overlap with humanities (English and other languages, management, economics, sociology, etc.), it would achieve wonders in making the student look for more options. Environmental sciences, hygiene, etc. become part of the general development rather than specialized isolated pockets and will truly reflect the interdisciplinary concerns.

All this can come only from a *professionally driven* basic science programme. An integrated 5-year M Sc is envisaged as such a programme (Tables 1 and 2).

Table 1. A suggested outline for a 5-year integrated *professional* M Sc programme in sciences

Year	Teaching	Project	Others
1st	Course work	Nil	Summer work
2nd	Course work	Nil	Summer work
3rd	Course work	Nil	Industrial training
4th	Advanced courses	Research/project	Summer training
5th	Nil	Research/project	

Table 2. A 5-year integrated *professional* M Sc programme in sciences: suggested style for structuring of contents. A similar style can be developed for physical sciences also

Course work	Theory	Theory, documentation, computation
	Practical	Manual/documentation
Skills	Practical	Photography, video, science art, instrumentation
	Project	Manual/documentation
Services	Teaching	Herbaria, greenhouse, jr. labs, data entry, tutorials, library, manual preparations
	Departmental	Data analyses, quality control of reagents
Maintenance	Teaching	Labs, library, etc.
	Departmental	2 h per student per a working week maximum
Research/project	Departmental	Last 1.5 years

It breaks several mind-sets and yet is doable collectively even as of now. Different universities will have different capabilities at different levels. Given importance to a final unification of postgraduate teaching, the focus will gradually begin in a small number of universities and the message will spread if successful. The very fact that these are integrated degrees will identify the degree holders. The postgraduate teachers can opt for their real love, teaching or research since conventional departments now become graduate schools. Regrouping of resources will conserve funds and enhance utilization. A five-year course will be found a favourite among parents too.

The real success of a teaching programme is when the student can make a conscious decision of what interests him and pursues it out of his own free will and not due to peer pressure. A science programme of 5 years multi-tiered and with multiple options can do just that. If it permits crossing between qualitative and quantitative sciences as well, we will really have something. The best salesman is one who offers whatever the customer needs. Some of our student customers will take to education, research and academics much due to their own liking. They will be smaller in numbers but will matter more and achieve more[14].

1. As Conan Doyle remarked, when you have eliminated the impossible, what remains, however improbable, must be the truth.
2. Sitaramam, V., *Curr. Sci.*, 1995, **68**, 89–94.
3. The university fosters each of these perceptions in certain ways *individually* while it is *collectively* a disaster. A change that threatens individual spin-offs of any of the three players is doomed, as is well documented even in the West.
4. Less than 5% faculty have an idea that creation of knowledge is also the primary statutory requirement of a university such as the Pune University.
5. The often used phrase in faculty debates is the word 'personal (overlapping with the terms isolated, individual, unshared, selfish) research' as opposed to departmental work.
6. When one speaks of paying propositions for degrees, one is banking on this aspect of the market since degrees and jobs are irrevocably linked, both representing the social need of employment guarantee schemes than any tailoring for mutual benefit.
7. The modern child psychologist is probably the strongest ally for the non-performing child and the indolent parent. There is a strong cultural objection to having an inferiority complex and not for being inferior. There is an urgent need to evaluate the impact of writings in Sunday editions and *Reader's Digest* that the parents read more than the impact of the idiot box that the child watches.
8. In Pune we hear of bai-technology, bai-logy, microbai-logy, bai-chemistry, and good heavens, even bai-tony.
9. Sitaramam, V., *Curr. Sci.*, 1995, **69**, 779–782.
10. The most obvious examples are the electron microscopes.
11. Is the research university in the United States dead, or dying, or under threat of extinction? And, on the assumption that there is something to salvage from what will otherwise be rubble, what can be done to revitalize the university? (John Maddox, in *Nature*, July 1994).
12. Money for biotechnology has all but dried up. There is a pervasive pessimism about the industry: A feeling that nothing works and none of these companies can be trusted . . . 'Are they [Biotech companies] arrogant, naive, and more than a little greedy, abandoning anything resembling scientific rigor and making outlandish promises' (*Bio/Technology*, October 1994).
13. Biotechnology management can be a specialization in a broad management course for a biology graduate and not the sole subject matter for a broad degree for a management trainee whose job opportunities may be elsewhere!
14. This paper is based on a presentation by V.S. to the faculty of Pune University on what can be done for the future of education in life sciences at the University.

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RESEARCH NEWS

Core–satellite hypothesis and the distribution of species: Why are species not found everywhere?

K. N. Ganeshaiah

How much we all wished that there was some matter left behind between the earth and the moon so as to form a bridge for us to take a moon-walk!! But we are told that the rules of gravity would not allow such bridges in our solar system and that such matter, if any, would have condensed into either the core-planets or into their satellites with nothing left behind between them. Unless one grapples with the meaning of gravity and the associated physical laws, it is rather difficult to comprehend how such loose matter could condense either into core planets or to satellites. An equally intriguing explanation termed 'core–satellite' hypothesis has been put forth[1–4] by the ecologists to account for a peculiar behaviour of the species while occupying their habitats.

Law of frequencies

Consider a habitat wherein a number of quadrats are laid and the occurrence of all the species in them recorded. Let us say we are interested in knowing how many species occur in only 20% of the quadrats (A), in 20 to 40% (B), in 40 to 60% (C), in 60 to 80% (D) and in 80 to 100% of the quadrats. As early as 1918 Raunkiaer[5] observed that generally the frequency distribution of species with these categories would be bimodal such that $A > B > C \gtrless D < E$. This is because every habitat shall have a set of dominant or the *core* species and a set of rare or *satellite* species; while the most abundant or the core species of the habitat occur in most of the quadrats (E), the rare species occur in a very small proportion of the quadrats (A). Accordingly, the