Are biotechnology degree courses relevant?

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Intensive research in biological sciences following the understanding of structure of DNA and its control of protein synthesis in living cells initiated the exciting field of molecular biology in the 1960s. Further basic research, using the ever-increasing sophisticated and precision methods, allowed better understanding of some of the more obvious ways in which the genetic information, inherited from parents as DNA molecules, functions. *Inter alia*, these studies also provided insights into the specific class of enzymes, the restriction enzymes, with which bacteria defend themselves by restricting or destroying the invader's genetic information. A good understanding of these and other enzymes that help DNA molecules to copy themselves in our cells was available by the early 1970s. Such knowledge made it possible to manipulate or modify DNA molecules or the genetic information in a test tube. This gave rise to the exciting field of genetic engineering. The power to manipulate our genetic blue-print in a desired manner fueled the desire of scientists, to some extent altruistic, to apply the knowledge of genetic engineering for benefit of common man. Thus the current version of 'Biotechnology' was born in 1970s. The initial altruism was, however, soon overtaken by the desire to exploit the unprecedented opportunity to convert intellectual property into material wealth. This has contributed to the unusually rapid establishment and wide appeal of biotechnology as a profession and an industry. With an unprecedented rapidity, paralleled in recent years only by information technology, biotechnology has affected not only the conventional paradigms of the industry, but has also changed the academic establishments.

After the more than three decades of biotechnology, it is appropriate to take stock of the expectations and achievements. The sky seems to be the limit for the hopes and visions generated by biotechnology. Possibilities include gene therapy, designer babies and other organisms, better food products from genetically modified plants, novel useful products from 'factories' based on microorganisms or animals/plants, freedom from disease and hunger, and so on. Everything appeared within the human reach. The scale of industrial investment and the rapidity with which the academic programmes are being changed across the globe in the face of these hopes, are truly unprecedented. However, the sustainability of this euphoria is now in doubt.

Adam Wilkins, Cambridge, UK, writing an Editorial in the December 2007 issue of *Bioessays*[1], compares the state of biotechnology with that of 'an industry that did not bother to get its fundamentals right'. He continues 'Biotechnology is, after all, a special form of engineering – one that involves living things rather than inanimate materials – and all engineering should be based on a proper scientific understanding of the materials that are being engineered. Imagine how far the *Apollo* programme, to land a man on the moon, would have got without a full understanding of the relationships between mass, force and gravity, the basics of electronic circuitry, the principles of rocketry, the basics of materials science, and much more. Yet, it would seem that much of the biotechnology industry attempted the equivalent of a moon shot without the necessary scientific foundations'. This, at least in hindsight, appears to be true and is indeed shocking. Biotechnology was, and continues to be projected as the panacea for most, if not all problems faced by humans in most countries. However, compared to high expectations and consequent investment of billions of dollars in the biotechnology industry across the world, there have been few success stories.

As a biologist, I wonder if some of these success stories, like the '*Bt*-cotton', would survive evolutionary forces: just as bacteria and mosquitoes (and other pests) quickly become resistant to ever-new generations of antibiotics and pesticides, it remains likely that the pests which are currently avoiding '*Bt*-cotton' may soon evolve novel metabolic pathways to survive the *Bt*-toxin. Such skepticism finds further support in the fact that although we claim to have deciphered the entire human genome, and genomes of a large number of other organisms, we still do not fully know the rules of grammar and syntax that the language of genetic information (DNA) follows. Our understanding of even the genes that actually produce the proteins or enzymes, that presumably control functions of a living cell and provide its unique properties, is far from complete. Our ignorance becomes much more glaring when we realize that the protein-coding part of the genetic information accounts for no more than 1.5–2% of the DNA that we inherit from parents. Scientists are just beginning to appreciate that the remaining 98% or more of the DNA in our cells, which till now was denigrated as 'junk' or 'selfish' DNA, is really not so[2]. However, how the bulk of this 98% DNA functions and how it interacts with the environment to make what an organism is, remain almost completely unknown. It is surprising that with such little knowledge, we feel confident that biotechnology can be harnessed to solve many of our woes!

Allured by the high hopes and hype, most countries have invested enormous resources, both private and public, in the biotechnology industry. The inertia of the massive investments and the consequent vested interests occlude the 'writing on the wall' that the simplistic and reductionist approaches, based on severely limited understanding of biology, that are being practiced in the name of biotechnology may collapse like an over-inflated balloon[3].

The above rather pessimistic statement, however, needs to be qualified. Applications of methods of genetic engineering and biotechnology, have indeed enormously helped improve our understanding of the nature of genetic information, its operational details, etc. This area of research needs to be continued more vigorously to allow really sustainable applications in future.

While the economic fallout of such a collapse is something that industries and economists need to worry about, I would like to point out another damaging aspect of the 'biotechnology' revolution in our country. This relates to our present state of education, especially biology or life sciences. Beginning in the mid-1980s, teaching programmes in biotechnology, initially at the Master's level, were started in India with great hopes of preparing adequately trained human resource, so

that the benefits of the emerging biotechnology revolution can be exploited maximally. In anticipation of the great expansion of biotech industry, there has been an unrestrained rush to learn/teach biotechnology. This has diverted both the younger minds and resources to the newly established departments of biotechnology in various universities and colleges across the country, at the expense of the existing departments of zoology/botany/microbiology/biochemistry, etc. Innumerable private and public institutions joined the bandwagon resulting in mushrooming of biotechnology courses in every city and small town of the country. Given the high population pressure and scant job opportunities, the younger generation and their parents have been easy prey to the belief that, like the information technology, biotechnology will provide a highly remunerative career. In this mad rush, a large number of young students pay whopping amounts as fees to receive, in return, a worthless certificate giving them B Sc/B Tech or M Sc/M Tech degree in biotechnology. In the wake of popularity of biotechnology and information technology, another field, bioinformatics, has also gained enormous popularity among aspiring students and teaching institutions that are out to 'make hay while the sun shines'. Biotechnology or genetic engineering are essentially laboratory based subjects and thus require extensive laboratory facilities for the students to learn and have hands-on training in different techniques. A majority of the innumerable colleges and university departments offering such courses have no laboratory facilities worth the name. Most of them have 'invented' a clever strategy which requires the hapless students to seek a place in other institution somewhere in the country (or even outside) to undertake a 'research project' lasting 2–6 months. The institutions where the students are enrolled do not provide any laboratory training, notwithstanding the fact that they collect substantial amounts as fees. On the other hand, the laboratory where the student undertakes the project is expected to foot the bill for the student's 'research training'. The plight of students who are required to undertake research projects outside the parent institution is no better than a 'beggar' on the street. Given the enormously large numbers of students 'begging' for projects across the country, the quality of research projects and their reports remains as bad as the quality of teaching in general. However, such 'self-financing' or 'special courses' continue to be very lucrative business propositions for earning money.

In addition to the above scandalous situation, one also needs to consider the academic relevance of teaching specialized subjects like biotechnology, bioinformatics, molecular biology, genetics, etc., at school or undergraduate level independent of teaching general biology, other sciences and social sciences/entrepreneurship, etc. Teaching of basic principles of biology is poor even in the traditional departments of botany, zoology, microbiology etc. It is worse in these specialized but popular courses. The syllabi in such courses are fragmented without any integration between topics in a given paper or between different papers. They are only peppered with some attractive and high-sounding terms, without providing for the connecting links between them and their biological relevance. Consequently, these students learn neither biology nor any technology. Absence of qualified teachers, combined with almost non-existent laboratory facilities, make the situation worse.

Since the biotechnology industry also did not have the expected growth, most of the biotechnology graduates come back to traditional departments to pursue their Ph D, where they did not want to study for their Bachelor's or Master's degree in the first place! The scale at which courses like biotechnology/bioinformatics have become popular can be gauged by the fact that 70–90% of applicants for Ph D in any life sciences/biology-related discipline in universities or more advanced research institutions hold a degree in one of these subjects (or their variants like marine biotechnology, agricultural biotechnology and so on). At the same time, the faculty interviewing such students or accepting them for Ph D complain that even though the students may be 'bright', they know little of anything! In this uncertain and fluid state, the established old departments of conventional biological disciplines have suffered because of lack of adequate financial support and good human resource in the form of bright students and capable faculty.

Unfortunately, the regulatory bodies like the UGC or the AICTE, etc. have failed to curb the mushrooming of such academically unviable and damaging teaching programmes. These courses have thrived on mis-guided enthusiasm, vested interests and media hype about the future that biotechnology offers. Undue publicity received by 'industrial placements' received by a small proportion of the burgeoning number of biotechnology graduates has added to their unjustified popularity. It is conveniently ignored that the biotechnology graduates often get placements in the corporate sector, where their knowledge of biotechnology is mostly irrelevant. They get such placements not because they have learnt biotechnology, but because they are intrinsically better/brighter. This is similar to the situation that most of the engineering/technology graduates become managers rather than engineers or technologists. In our currently globalized and money-driven society, we are forgetting that we spend enormous public money in (mis-) training young citizens of the country in certain 'fashionable' fields, but the training received by them is of little relevance to what they ultimately do in their life. Consequently, the entire expenditure (investment) goes waste. With a large proportion of children not even able to get primary education, such meaningless wastage of public money is certainly not justified.

It is high time that all school and undergraduate stand-alone teaching programmes in biotechnology/bioinformatics, etc. are stopped and even the M Sc programmes in such disciplines are made integrative. Without the necessary background knowledge of basic general biology, genetics, cell biology, development, evolution, etc. it is not possible to understand the methods and appreciate the principles of their manipulations. The country needs to urgently revive the life sciences-related teaching departments in various universities to provide a more holistic education that stimulates the students to ask deeper questions rather than just learn some so-called modern techniques in the elusive hope of quick material benefits. It is essential to learn the methods and principles of biotechnology, bioinformatics etc., but these must be learnt in the background knowledge of biological organization.

1. Wilkins, A. S., *Bioessays*, 2007, **29**, 1179.
2. Mallik, M. and Lakhotia, S. C., *Proc. Natl. Acad. Sci. India*, 2007, **77** Spl Issue, 43–50.
3. Lakhotia, S. C., *Bioessays*, 2008, **30**, 288.

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