# Are our universities producing too many PhDs?

Bruce M. Alberts

As we enter the 21st century, we face a world that will be increasingly dominated by science and technology. More and more jobs will require many of the analytical and thinking skills of a scientist. Citizens everywhere must also become better able to evaluate and understand the judgements of scientific and technical experts when making personal and community decisions. To spread the values and knowledge of science much more widely throughout our societies, we must also spread scientists. Therefore, advanced training in science and the acquisition of important skills through an extensive exposure to research are valuable tools for a wide variety of occupations.

As I write this article, I have just returned from speaking at yet another large graduate-student retreat. As usual, my topic was science and the importance of spreading both the skills and the values of scientists throughout the USA and the rest of the world. I try to attend several of these events each year, so that I can reflect accurately the current hopes and concerns of the next generation of scientists in my many discussions with policymakers. I always find the energy and idealism of these young scientists invigorating, and I continue to be impressed by their willingness to consider a wide range of career options. Even at the most prestigious institutions, there are many graduate students and postdoctoral fellows who talk freely to each other about their interest in careers in teaching, journalism, science policy and government – in addition to the traditional scientific research career in a university or in industry.

Among graduate students, I see a major change from an attitude that seemed to prevail as little as five years ago that 'only those who can't excel in research could want to do anything else for the rest of their life'. The reasons for this change are no doubt complex. Many see the lifestyle of a professor as increasingly harried, and they feel that present-day science is too competitive for their taste. Others were attracted to science because of its broad scope and the intellectual excitement that they derive from the outpouring of new discoveries, and some of these students feel that the future research projects available to them are likely to be focused too narrowly to accommodate their wide interests. And last but not least, students around the world have read reports of an excess of PhDs in many fields, relative to the number of permanent research jobs[1–4]. So, as a practical matter, it is merely common sense to consider seriously a larger set of career options.

## The facts about PhDs

It is in this context that a 1998 report[5] from the National Research Council (NRC) added fuel to the fire of a vigorous, ongoing national debate as to whether 'there are too many PhDs' being awarded to scientists in the USA today. Because of the many concerns that we had been hearing from young scientists – both graduate students and postdoctoral fellows – a special committee was established by the National Academies (the National Academy of Sciences, the National Academy of Engineering, the Institute of Medicine and their 'operating arm' – the NRC). This committee was charged with the task of investigating the facts with regard to the life sciences. How many PhDs have graduated from universities in the USA in recent years? Has this number been increasing at a rate that seriously exceeds the increase in jobs available for these talented people in colleges, universities and industries? If so, what happened to all of these life-sciences PhDs? Could we expect enough job openings in nontraditional careers to make up for the difference?

The NRC Committee was chaired by Shirley Tilghman from Princeton University, and its report, entitled *Trends in the Early Careers of Life Scientists*, is full of detailed graphs and tables. Like all reports from the National Academies, the full text is freely available on the World Wide Web[5]. Among the findings were that, as of 1996, nearly 8000 PhDs were being awarded per year in the life sciences, a number that had been growing by about 4% per year since 1987 (Fig. 1). Over this same period, the number of traditional permanent positions for these PhDs had also been increasing – mostly in industry – but at a growth rate of only about 3% per year. Therefore, if these trends were to continue, the size of the already large pool of about 20 000 life-science PhDs holding temporary, low-paying research positions as postdoctoral fellows might be expected to increase by thousands of scientists per year.

As others have also pointed out[1–4] (see also Box 1), such an increase in postdoctoral fellows cannot be sustained indefinitely. Many of the energetic and talented undergraduate students who presently seek to become PhD scientists will obviously choose to take their chances in other careers if they sense that they are likely to become 'perpetual postdocs', with a typical annual salary for those in the life sciences of about $25 000.

## What can we change?

As I see it, the scientific community is presently faced with several options. The easiest one is business-as-usual, letting the strident feedback that we can expect from an increasingly disgruntled cohort of PhDs discourage college students so that the number choosing science careers falls drastically. I believe that such a 'free-market approach' would represent a major setback for science, not only because of the demoralization that it will produce among our young scientists, but also because we could lose access to a major fraction of the young talent feeding a merit-based selection for those who will become the outstanding scientists of the next generation.

What are some other options? Our universities and granting agencies could try to create more semi-permanent research jobs by encouraging the support of selected PhDs as senior laboratory managers for many of the research faculties in our universities[3]. However, such positions are often eliminated by today's peer reviewers, who generally view temporary postdoctoral fellows as a much cheaper, more effective alternative. And faculties generally prefer the present system, which provides access to a supply of eager young apprentices for whom they have no permanent responsibility. For these and other reasons, changes of this sort will not come easily.

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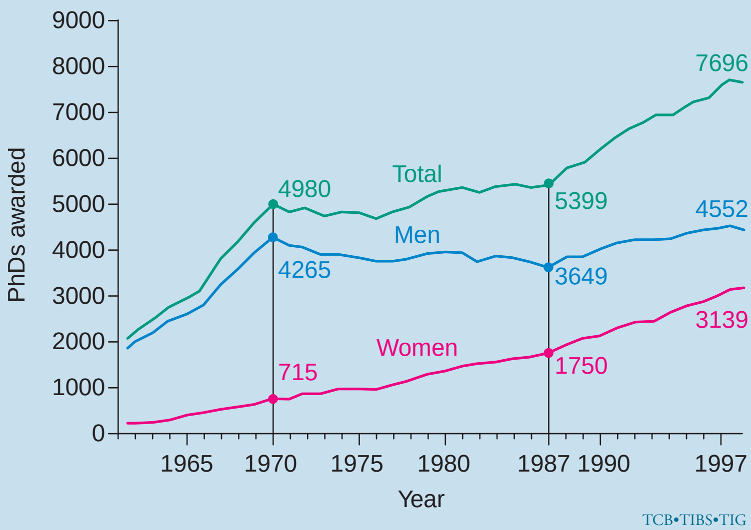


**FIGURE 1.** The number of life-science PhDs awarded annually in the USA from 1963–1997. The actual numbers are given for 1970, 1987 and 1997. This is an updated version of a figure that appears in Ref. 5; the sources of data and scientific fields covered are listed in Appendices C and D of that document.

At any rate, they will certainly not be sufficient to solve the problem that is faced by most of today's postdoctoral fellows.

## A future in education?

We all know science as a marvellous and highly effective way of learning about the world. From this knowledge, we continue to derive, often quite surprisingly, tremendous practical benefits for humankind[6]. Science also teaches us that the natural world is a rational place, one in which there are many regularities that we can use to protect ourselves from harm and remove the fear that can come from a lack of such understanding. However, there is also a major problem with science. This was well stated in a recent book on this subject: 'Neither the proverbial man-in-the-street nor many of those… in the humanities have any real understanding of what scientists do or how science works. Science has become a form of magic, practised by an elite priesthood whose members have been subjected to a long and arduous apprenticeship in secret arts and rites, from which the layman is firmly excluded'[7].

To help address this problem head on, the National Academies led the development of the first-ever *National Science Education Standards* for the USA in 1996[8]. These voluntary standards call for a revolutionary change in the education that we offer to all students – an education in which science becomes a core subject in every year of school. Most importantly, the emphasis is on active science that is taught for understanding, with the goal of giving every student the ability to reason like a scientist and to 'learn how to learn through inquiry'[9].

At this point in this brief essay, I will startle most of my friends and colleagues in the scientific community by making a bold proposal. As the NRC report on life scientists pointed out, there is one career that could easily employ many thousands of PhDs each year to good advantage, as required to balance the present influx of PhDs. This is a career that is focused on providing a new kind of science and maths education for 5–18-year-olds.

Is a PhD overqualified to teach science in a school? I believe that a deep immersion in scientific research provides one with skills and attitudes that are invaluable for many professions. In particular, experience with school-system reform shows that we cannot expect teachers to do a good job of teaching science through inquiry if they have never had a meaningful experience with scientific inquiry in their own education. It is a sad fact that most of the students who graduate from college today – even many with a major in science – have very little understanding of the processes of science and have never had an opportunity to engage in the process of scientific inquiry themselves. We therefore face a serious chicken-and-egg problem: we cannot achieve an effective rejuvenation of science education at lower levels unless we first change both the nature and the extent of the science that is taught to all those college students who will soon become the elementary-, middle- and high-school teachers of the next generation[10].

Over the course of the next ten years, the USA will face an unusually large demand for teachers, with an estimated 2 million teachers needing to be hired out of a total of 3.5 million[11]. Science and maths teachers will be in especially short supply, and there is an urgent need to replace the retiring generation of talented leaders who moved into science and maths teaching during the post-Sputnik reforms of the 1960s. Similar problems are faced by many other nations around the world.

I view the current situation as a terrific, once-in-a-lifetime challenge for the scientific community: can we harness some of the enormous energy and talent that resides among our graduate students and postdoctoral scientists to reinvigorate our school systems? My own contacts with young scientists have made me aware that many of them are willing to try the teaching profession, provided that efficient training programmes become available to supply them with the additional skills they will need to teach well, that we in the scientific community demonstrate our support for such a career change by continuing to treat them as colleagues once they become teachers, and school systems show an eagerness to hire and support these scientists adequately once they have been trained. At the same time, my contacts with the nation's scientific elite has convinced me that they are now willing to pay attention to this issue in ways that were never possible before – in part because they see that finding a new career pathway that satisfies a large number of the young scientists whom they are training is important for the entire scientific enterprise. In the longer run, we will need to raise the status of teachers in our society, and we must pay them salaries that reflect the crucial importance of their profession. Moving large numbers of PhDs into our schools as teachers and leaders, and keeping them closely tied to the scientific community, is a good way to start such a revolution.

## Should we be generating fewer PhDs?

From my perspective, we can never have too many PhDs – people who have a deep understanding of science and scientific inquiry and who are excited about science and in touch with at least one of its frontiers. These are the people who are best qualified to communicate the nature of science and to impart scientific abilities to others. They can also spread the values of science – honesty, generosity, a respect for evidence and an openness to new ideas – as needed for the world to prosper in the 21st century. We need people with these abilities to work in many different

### BOX 1. Life as a postdoc

An extensive review of experiences of PhDs and viewpoints of experts on the PhD systems in the USA, Europe and Japan was published recently in *Science*[1]. One can participate in an ongoing debate on the issues raised in the special report on a dedicated Web site (`http://nextwave.sciencemag.org/discussions/`).

**Reference**

1 Postdocs working for respect (1999) *Science* 285, 1513–1535

occupations throughout our societies – not only in schools, but also in governments, the media, law and in a large variety of businesses and community organizations.

What is presently lacking for most graduate students today is a good sense of their options. Many of these students discover rather quickly that they either lack the motivation or the talent needed for a lifelong career in a research laboratory. However, by this point, they are often locked into an inertial pathway driven by faculty expectations and fellowship-funding patterns that propel them not only through the PhD degree but also into one or more postdoctoral research positions. It is up to the faculty in research universities to facilitate other career paths for such students, and this requires an unnatural act: the active encouragement of a variety of student career interests that require scientific skills but do not focus on research[12,13]. Most science faculties know very little about such nonresearch careers and, for this and other reasons, they are poorly equipped to help their students in this regard. This situation must change if we are to create a balanced production of PhDs that provides satisfactory careers for everyone, as needed to sustain the enthusiasm of college students for pursuing graduate training in science[14].

In this context, it is important to recognize that there is no accurate way to predict which college graduates will become tomorrow's leaders in scientific research. The combination of skills that is required for repeated success in scientific inquiry – analytical ability, perseverance, creativity, a penchant for risk-taking, optimism, energy, communication skills and objective self-evaluation – is much too complex to be assessed by course grades and exam scores. In our graduate schools, the students have a chance to work as apprentices, testing themselves in a realistic research environment. In my experience, no one knows – neither the professors nor the students themselves – which of the graduate students in each entering class will turn out to have the talent and the motivation required to become leading researchers. But, by the time the students complete their PhD degrees – four, five or more years later – most of them will have gained a pretty accurate sense of their capabilities and interests. The National Academies are focusing on these crucial issues, which I believe to be of utmost importance for the future of science, as well as for the future of our schools. I invite all those with an interest in the issues raised in this article to keep in touch with us through our Web site (`http://www.national-academies.org`).

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## Biochemistry 2020

In 1995, TiBS readers were challenged to predict the contents of an undergraduate biochemistry finals paper in 2020 (the winner was Frank Siegel). This competition was inspired by a similar exercise conducted by the Editors of *Brighter Biochemistry* in 1931, when they predicted the 1956 exam paper for the University of Cambridge, UK, Natural Sciences Tripos Part II. Below are some of the questions penned in 1931 and 1995.

**Natural Sciences Tripos Part II 1956**

'The beginning of consciousness in the developing hen's egg can be placed with certainty on the 19th day' (Needham and Holmes). Describe the substances which determine the appearance of this function, and the analytical methods employed for their detection.

'Taxonomy must in future be based on biochemistry' (Haldane). How have the conifers been reclassified on the basis of their terpenes?

Write an Essay: The biochemical account of muscular contraction is now complete.

**Biochemistry exam 2020**

Indicate the biochemical mechanism by which immune function is affected in any specific neurological disease.

For any specific gene of your choosing, discuss the mechanism of action of any one enhancer element and one silencer element, indicating their corresponding *trans*-acting factors and the mechanisms by which these *trans*-acting factors affect transcription.

Biological scientists were startled when in 2006, Mars Explorer recovered a primitive photosynthetic nematode which had DNA but no detectable RNA. Describe the studies of Evans and Kamaguchi that elucidated the mechanism of protein synthesis in this organism.