Are appropriate numbers of scientists being trained for research in immunology? Available data suggest that supply is not yet outstripping opportunities. The form of those opportunities, though, should change.

Careers in immunology: the new reality

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There has never been a more exciting time to conduct immunology experiments or a more disquieting time for immunology trainees. Extraordinary advances in technology allow rapid erosion of once intractable issues while confusion surrounds career prospects. Immunology students who are better trained and more talented than ever before are told that permanent jobs are scarce. Thoughtful studies have concluded that biomedical training programs should be capped while many laboratories complain of a shortage of good people. We examined statistical data on education, employment and research opportunities to determine whether proposals for change were appropriate for immunology. There has been a slow expansion in the numbers of immunology Ph.D.s and postdoctoral fellows during the last ten years with very little growth in faculty level positions or numbers of National Institutes of Health (NIH) grant applications submitted. In contrast, the amount of inflation-adjusted funding for experimentation nearly doubled over the same interval. Changes are taking place in workforce needs and career prospects in immunology that need to be closely monitored. Although there is insufficient data to support recommendations to restrict training, it may be time to restructure the opportunities in this field. Specifically, we recommend recognizing the importance of staff scientists, expanding this job category and introducing trainees to this career path at an earlier stage.

Emerging role of the staff scientist

Recent reports[1–3] have endeavored to improve the focus of biomedical research training in an attempt to better match training efforts with anticipated needs. Proposed remedies for the perceived problems may have merit but we have not identified a serious crisis in relation to supply and demand for immunologists; the data that support this position are summarized below. Rather, the changing character of opportunities for new investigators may require reconsideration of what a successful career entails[4].

Many institutions now have a few “research-track” slots that lack the “up-or-out” pressure of tenure-track positions and it can be argued that the individuals in these jobs are the most highly trained and stable part of our workforce. These scientists generally have advanced degrees and often come to these positions *via* extended postdoctoral training. Immunologists could be encouraged to deliberately make this career choice at an earlier stage and without necessarily remaining in their training sites. The median age of bioscience Ph.D. recipients is now 31 years[5] and childbearing years can be quickly used up with extended postdoctoral training. The security of a relatively permanent staff position along with parental leave, childcare and other benefits would make this a particularly attractive option for some individuals. Staff scientists have most of the privileges enjoyed by principal investigators but more time for hands-on experimentation. These positions should allow substantial career growth and need not preclude options for teaching, publication and grant submission.

As research teams tend to grow larger, there is an increasing need for supervision and training within them. Additionally, growing sophistication in technology and dependence on core facilities demands highly skilled and innovative scientists to run them. For all of these reasons, we recommend that staff scientists be more actively recruited, adequately compensated and recognized for their unique contributions to biomedical investigation. Institutions may be forced to develop stable, long-term contracts and support for the new life-blood of science. Exciting developments in immunology have increased the demand for this talent and we should seek ways to make it a coveted career objective.

Graduate training: what are the trends?

How well does our current training system meet the needs of modern immunology? Many successful immunologists have trained in fields such as medicine, biochemistry and cell biology. Consequently, no database identifies all individuals preparing for work in immunology. However, graduate enrollments in microbiology, immunology and virology have been relatively stable for the 1990–1998 period, at approximately 5,000 students (**Table 1**). Enrollments rose in the early 1990s, reaching a slight peak in 1994 before declining gradually. In 1999, graduate enrollments for these fields were nearly identical to those of 1990[6,7]. A similar pattern is found for National Institute of Allergy and Infectious Diseases (NIAID) predoctoral traineeships in immunology. The number of these positions increased from 178 in 1990 to 231 in 1992 and remained near that level for the rest of the decade.

Doctorate awards in biological immunology and microbiology rose from 488 in 1990 to 629 in 1998[8]. This represents an increase of 28.9% (an average of 3.6% per year over the 8-year period). Most of this growth occurred during the early 1990s and for most of the decade the number of new Ph.D.s has been fairly stable, around 600 per year. Reflecting this stability, membership in the American Association of Immunologists (AAI) grew only about 1% per year during the same interval.

Postdoctoral training

Several recent studies have drawn attention to rapid changes occurring in the postdoctoral phase of research training[9]. In biomedical sciences as a whole, there has been a substantial expansion in numbers of postdoctoral trainees and the average length of time spent as a postdoctoral fellow has increased. We found that growth in the number of microbiology, immunology and virology postdoctorates was modest but greater than that for graduate students or new Ph.D.s (**Table 1**). In 1990, there were 1,469 postdocs and by 1998 this number had increased by 43.6% to 2,109[6,7]. It should be emphasized, however, that nearly half of this increase occurred between 1990 and 1991, with very modest expansion of this cadre since 1994. We can get more focused information on immunology from numbers of postdoctoral trainee and fellow positions awarded by the NIAID but these are restricted to US citizens and permanent residents. There were 284 of this type of NIAID-supported fellow in 1990. The number of positions grew in the early 1990s and then contracted so that by 1997 there were 294 NIAID postdoctoral trainees. The program has remained at this level since then. These indices suggest that there has not been explosive growth in numbers of immunology postdocs and certainly not in ones that are permanent US residents.

Principal investigators in immunology

Many immunology students desire an academic career and the opportunity to compete for independent research support as principal investigators. This goal is achieved by some with positions in nonprofit research institutes, government laboratories and biotechnology companies but we expect that most immunology principal investigators are affiliated with universities and medical schools. Because NSF reports on science and engineering personnel do not show faculty positions by discipline, data on immunologists is limited. AAMC reports data on medical school faculty positions by department but there is no separate breakout for immunology[10]. However, AAMC data are available for microbiology departments that probably house a majority of immunologists. In addition, the microbiology category roughly corresponds to the ones used above for graduate students, new doctorate recipients and postdocs. In 1990 there were 1,697 microbiology faculty positions in medical colleges. This number rose to 1,858 in 1999, an increase of 9.5% (averaging 1.1% growth per year over the 9-year period). Numbers of grant applications referred to the NIAID provide another measure of principal investigators in immunology. NIAID grant applications fluctuated around 2,100 for most of the decade with a significant rise only taking place in 1999.

The new investigator

If the most prestigious career in immunology involves an independent laboratory, the above data suggest that new opportunities of that type are not growing rapidly. On the other hand, new investigators represent the life-blood of science and steps are being taken to monitor and encourage their success. In 1997, the NIH Working Group on New Investigators examined funding trends and concluded that new investigators were not being well served by the R29 category of NIH grant[11]. The fixed amount of the awards was viewed as insufficient and the designation thought to be inferior relative to R01 grants. For those and other reasons, R29 grants were eliminated in 1998 with assurances that applications from first-time grant writers would be clearly identified to review groups. In 1995, NIH made 1,413 R01 and R29 awards to previously unfunded applicants. The number of R01s rose to 1,623 in 1999. NIH has concluded that the elimination of R29 grants did not decrease success rates for new investigators and at the same time made substantially more money available for their studies[12].

The same NIH Working Group on New Investigators estimated that a relatively constant 9% of scientists leave the NIH grant system each year. In 1999, there were a total of 19,599 researchers with R01 or R37 grants, which included 1,623 awards or 8.3% that were received by new investigators. It is important to monitor such trends carefully to ensure that the sufficient infusion of new immunologists maintains at least a steady state.

Growth in funds for immunology research

Support for research in immunology expanded dramatically during the 1990s. As a rough approximation, we examined funding trends for extramural research grants awarded *via* the NIAID. The number of NIAID awards increased from 567 in 1990 to 908 in 1999 (60.1%, an average growth of 6.7% per year). Total funding for NIAID awards rose even faster. Adjusting for inflation, it increased from US$112,596,000 in 1990 to US$213,834,000 in 1999 (an increase of 89.9% with an average increase of 10.0% per year). Some of the increase in research support may have been absorbed by more expensive methodologies. Even so, funds for research in immunology have clearly expanded more rapidly than the number of newly trained scientists. This imbalance may account for anecdotal information about a personnel shortage, frequently stated as: “there just aren’t enough good students and postdoctoral trainees”. In reality there may be a rising demand for experimentalists at the bench.

Limitations of the data

Recently there have been several major studies of the USA’s capacity for educating scientists[2,3,13]. Using the same survey databases, these studies have drawn similar conclusions about what has happened to the scientific workforce. There is far less agreement, however, about what should be done to change the number and characteristics of the new scientists being trained. Extrapolations of past trends are notoriously fallible as predictors of the future and such efforts are unable to anticipate major events that have a huge impact on the supply and demand for scientists, for example, the launching of Sputnik, the end of the Cold War, the Tianamen Square massacre, the emergence of the Internet and the increasingly successful effort to double the NIH budget in five years.

The time required to collect and process data from national surveys further diminishes the value of these data sets as guides to the future. The evaluation of the NIH training and fellowship programs, for example, which was published in September of 2000, had to rely on data from a 1997 survey[3]. Even the most comprehensive surveys (those conducted by and for the National Science Foundation) often provide only a partial perspective on the USA’s science resources. In the biomedical sciences, for example, there are no comprehensive data for physician-scientists.

Additional obstacles arise from the use of different classifications of fields and different levels of aggregation. For example, the NSF survey of doctorate awards breaks out data for biological immunology, whereas the NSF surveys of graduate students and postdocs report microbiology, immunology and virology combined. Reports that rely on the NSF-sponsored Survey of Doctorate Recipients are constrained to current findings in aggregate categories such as “biological scientists” because the cost and response burdens associated with this detailed, longitudinal survey of career outcomes dictate the use of a sample of the population of scientists. There are insufficient numbers of respondents in each detailed subfield to permit accurate estimates at the specialized-field level.

Table 1. Trends in training, employment, and research support for immunology, 1990–1999

Source	Fiscal year										Annual
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	change (%)
Microbiology, immunology and virology graduate students[a]	4,873	4,928	4,972	5,068	5,141	5,072	4,963	4,854	4,824	-0.1%	
NIAID predoctoral training positions[b]	178	197	231	237	221	230	220	247	247	243	4.1
Biological immunology Ph.D.s[c]	153	177	181	169	161	190	238	214	245	7.5%	
Microbiology Ph.D.s[c]	335	372	377	433	423	426	444	409	384	1.8%	
Biological immunology and microbiology Ph.D.s	488	549	558	602	584	616	682	623	629	3.6%	
Microbiology, immunology and virology postdocs[a]	1,469	1,715	1,784	1,881	1,924	1,943	1,975	2,019	2,109	5.4%	
NIAID postdoctoral trainee and fellowship positions[b]	284	327	367	360	319	280	262	294	293	297	0.7
Full-time faculty positions in medical school microbiology departments[d]	1,697	1,772	1,900	1,868	1,819	1,831	1,850	1,896	1,899	1,858	1.1
NIAID grant applications[e]	2,132	1,894	1,912	2,094	2,480	2,209	2,098	1,993	2,191	2,681	2.9
NIAID grant awards[e]	567	571	548	582	606	549	666	860	805	908	6.7
NIAID grant funds (thousands of US$)[e]	112,596	130,176	164,197	162,172	138,298	147,439	210,833	226,933	217,206	293,728	17.9
Biomedical R&D price index[f]	100	95.4	91.4	88.3	85.1	82.2	80.2	78	75.4	72.8	
NIAID grant funds (constant thousands of US$)	112,596	124,188	150,076	143,198	117,692	121,195	169,088	177,008	163,773	213,834	10.0
Membership of the AAI[g]	4434	4562	4642	4731	4705	4718	4735	4774	4735	4748	0.8

[a]See refs. 6 and 7. [b]M. Hernandez, NIAID/NIH, personal communication. [c]See ref. 8. [d]See ref. 10. [e]NIH website at www.nih.gov [f]See ref. 18. [g]AAI, Bethesda, MD, USA.

Detailed surveys conducted at a single point in time lack comparative perspectives. Some researchers have attempted to artificially create a longitudinal perspective by contrasting views of older and younger scientists. But this blurs the distinctions that arise from a number of different sources: age (career development), time period (historical circumstances) and attrition (survival)[4].

Surveys conducted by professional associations[14,15] or research institutions[10,16] are valuable but do not cover individuals as they move out of the sponsoring organization and into other realms of research. Studies of specific fields or specific disciplines are hard to link with other databases. Scientists may move from one subfield to another with relative ease and the classification of their activities may vary even when the work they are doing remains the same.

The NIH, NSF and National Research Council have taken significant steps in recent years to standardize and coordinate the use of typologies for scientific fields but more needs to be done. While preserving important time-series data and allowing special purpose studies the discretion needed to obtain relevant information, more emphasis needs to be put on the collection and reporting of data in comparable categories. It would be very helpful to have a typology of biomedical fields that captures some of the major research areas without resorting to categories that are too small to be analytically useful.

It would also be helpful if the NIH could make more data available for policy studies. We hope that the full implementation of the new IMPAC-II computer system will enable researchers to analyze funding and training patterns. Adequate funding for these activities must be forthcoming to ensure the responsible stewardship of valuable research resources.

Conclusions

While carefully focused information would allow more incisive recommendations about careers in immunology, some trends seem obvious. At first glance it seems that the prospects for careers as independent investigators are tightening because the growth in full-time academic positions is even less than the modestly increased numbers of immunology Ph.D.s and postdocs. However, of special note is the increased availability of funds for immunology researchers and the possibility that a workforce shortage exists for some categories of research personnel. This would certainly be the case if there were increased opportunities for immunologists in biotechnology and pharmaceutical companies. At the aggregate level, we know that there has been an expansion of industrial employment of biomedical scientists. Although statistical data on immunologists in industry are limited, one report that uses special tabulations from the Survey of Doctorate Recipients showed that the number of immunologists employed in industry rose rapidly in the early 1990s and doubled between 1991 and 1995[17].

These findings are not supportive of a cap on immunology training. In addition, it should be noted that an exact match between students enrolled and expected research positions is a misguided goal. There will be some students who, as a result of their experiences in graduate school, realize that they do not wish to pursue a research career. Others will be found to lack the necessary aptitudes and abilities. Then there will be those students who have plans for careers outside the laboratory who determine that a doctorate is desirable for job advancement, personal satisfaction or other reasons. They should not be prevented from entering or completing advanced training in immunology. Additionally, it is not possible to predict how much the next decade will resemble the past. Although we can probably expect continued expansion of research funding, the amount is not known. The need to replace the 9% of immunologists that retire or leave research each year is certain. Additional talented scientists are needed to harvest the opportunities created by advanced technology, increased research resources and the need to protect against emerging infections. It is also clear that the applications for immunology in cancer therapy, transplantation and other important areas will expand as we learn more about how the immune system can be manipulated.

This would seem to be an ideal time to expand research faculties at medical schools and private research institutes, even if teaching needs have remained constant. Increased utilization of well compensated and fully appreciated staff scientists would provide one means to capitalize on emerging opportunities in immunology. Another goal must be to attract even more talented students to a field that remains important, exciting and fresh.

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