MANPOWER DYNAMICS OF A SCIENTIFIC FIELD

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Most, but by no means all, young people in the United States graduate from high school. But of those who do, only some 21% ever take a high school physics course, and only 9% take one in college (see PHYSICS TODAY, August 1989, page 30). America's success or failure in scientific and technical endeavors rests largely in the hands of this latter cohort; and of it only a minuscule 0.4% go on to get a doctorate in physics. The weeding out of the age cohort is perhaps 3000:1. Yet there is a nagging employment problem among PhD physicists. Assuming even marginal rationality of our social structure, this tells us something: The US doesn't need very many research physicists. Be this number only those currently employed or (optimistically) be it somewhat larger, it certainly is small. To be blunt, we may safely assume that we are at or near the asymptotic limit of our profession.

Not all physicists belong to the American Physical Society. But if we take its membership totals as an index, then it would appear that our profession has now plateaued at around 40 000 members. From 1920 to 1970 our numbers grew roughly exponentially, with a doubling time of about 12 years. This was followed by stagnation in the 1970s and by much slower growth since. We seem to have saturated the market, and there is no military or industrial or educational reason to project a growth spurt to a markedly higher plateau. True, physicists could (at the cost of some opprobrium) devise more devilish weapons, but there is no sign that the government either needs or wants them. True, physicists could collaborate in the production of better things for better living, but there is no compelling evidence that American industry will hire us in preference to some other discipline or, in this era of downsizing, hire anybody. (The way things are tending at present, it could even be questioned whether industry will *retain* anybody.) True, physicists could display the wonders of science and technology to a generation of untutored youngsters, who certainly are going to need such understanding to flourish in the 21st century, but who among us can rationally believe that most of those youths will appear (except at gunpoint) in our classrooms or that their parents and neighbors will ante up the requisite resources?

Let's get real. We've got about as much of the pie as we're going to get. And since the pie shows little sign of getting fatter, we must prepare to live with a fixed market for physicists in general and for research physicists in particular. As with biological species or economic entities, this will inevitably lead to stiffening competition for resources and a milieu in which only the fittest survive. (And "fittest" is here to be determined after the fact by the objective evidence of survival. Hence the elegance and rigor of one's papers or the mesmerizing quality of one's lectures or the manufacturability of one's designs are not evidence of fitness but rather explanations that might be cited by historians as having contributed to one's survival.) Realistically, in any field, we can expect this competition to intensify until it stops just short of mutually assured destruction of that field's psychologically battered survivors.

Naturally, those of us who are already established as research scientists find this prospect gloomy and might be tempted to institute various schemes to circumvent it.

For example, to use a National Institutes of Health model for disbursing funds, some of us might acquire dominance in a study section and tilt the playing field to keep our in-group funded and inhibit interloping competitors. Never mind that this is dishonest and dishonorable: It won't work in the long run. Because as soon as our dominating group becomes less fit, our study section's budget will shrink while the budgets of fitter sections grow. All we conspirators will have done is postpone our group's demise. If we fantasize putting one of our group into the Presidency to stabilize the tilt, that too will only postpone the evil day: We domestic fat cats ultimately will be obsoleted by leaner and harder competitors overseas, and the continuing support of our feeble endeavors will become a major political embarrassment.

We might contrive to ease competition by sharing all the (limited) available funds equally among a certain group of chosen individuals. Perhaps all full professors of physics at doctorate-granting institutions could be given a fixed and equal research stipend every year. But this won't work either. First, some endeavors are intrinsically more costly than others, and this strategy would doom the United States to mediocrity in those areas. Second, human nature being what it is, some recipients would fritter away their stipends in lackadaisical and lackluster activities that lead nowhere. This sort of fat-cat consortium would last only as long as it takes American science and the American economy to go squishy, at which time the electorate would demand that its scientists, one and all, be the leanest and meanest predators in the jungle.

When we started grad school, it certainly didn't seem that we'd all signed on for careers of perpetual stress. But to paraphrase one of Akira Kurosawa's samurai, "In defeat you must run. In victory you must run. When you can no longer run, you die."

What makes it worthwhile for us is that the stress is accompanied by ongoing fulfillment punctuated at rare intervals by moments of transcendent satisfaction. We look forward to going to work in the morning!

But on to the real point of this essay. If neither we nor our legislators try to fiddle with the outcomes and if equitable competition is allowed free rein, what might the population dynamics of doctoral-level

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physics in the US come to look like?

First of all, "physics" as a category is too broad. The problems and opportunities of condensed matter persons are not those of biophysicists. Better we should talk of "fields" of scientific endeavor, bearing in mind that, like biological species, these evolve, flourish and eventually go extinct: Nothing lasts forever.

Second, given the diversity of modern science and technology, an economy (even that of the US or Japan) cannot hope to underwrite competitive advantage or even a presence in all fields. If your heart's desire is to work in field X, you may have to migrate to where X is hot stuff. An economy that strives to achieve hegemony in all fields has doomed itself to near-universal mediocrity.

Third, a nation's economy can, even for a favored field, support only so many practitioners. Let that number be N. The lifetime L of an active practitioner (a researcher) is limited: Surely 50 years is pushing it; conversely, the nation probably made a bad investment if it doesn't get at least 20. If we ignore the obvious reality that many of us voluntarily migrate between fields (to say nothing about frantically abandoning ship if our field sinks), this means that we need a steady-state input of only N/L new practitioners a year, and this necessarily is a small number.

Where do those N/L new practitioners come from? Well, ignoring migrants entering from other fields, they come from graduate programs. Here, a truly free market will ultimately recognize that megaprograms grow unwieldy—just ask GM or IBM. Conversely, programs that put out virtually no one are seldom competitive: Graduate students need peers to interact with, and they need specialty courses to take. Administrators are prone to balk at underwriting courses in which only one or two students enroll. And faculty aren't too keen on teaching them as "voluntary overload." What it boils down to is that world-class programs, which an economy must have to continue hegemony in a chosen field, will produce an average of G graduates per year. We could argue how big G is, but almost no one would set G at less than 2. And above a dozen, unwieldiness might be suspected. Either way the implication is that only N/LG programs are needed. For example, if L is taken to be 30 years and G is chosen to be 10 graduates per year, then a specialty field of 2700 members can be serviced by only 9 programs. It goes without saying that no single university can support competitive programs in all fields of endeavor. And therefore, sooner or later, many of us in academia will watch with horror as our research field is zapped. Ultimately, we may decide that undergraduate education is a noble and even rewarding endeavor.

The fortunate faculty members who run a successful doctoral program will all recognize the desirability of continuity in their personal endeavors and will as individuals become irritable if they go too long without producing a PhD. Most of us would prefer to space our graduates not more than three years apart, and probably we would prefer one or two years. That is, each program can get by on perhaps $2G$ faculty. Indeed, in a lean and mean professional environment, more would be wasteful! The implication is that only $2N/L$ "breeding" faculty are truly needed: Only 2 in L (approximately 30) of us are really necessary to keep the field stocked, and the rest of us probably shouldn't "reproduce."

The modern paradigm of academic basic research is that graduate students and postdocs perform much of the direct labor while their mentors compete for the scarce resources needed to support them and the project. If we can't crank out PhDs and if our time is preempted by teaching, committees and fund-raising to maintain the infrastructure required to carry out the basic research, how, pray tell, is the work to get done? Possibly by encouraging master's degree theses, at least while the industrial demand (such as it is) for such persons holds up. Possibly by adopting research as our recreational activity of choice, if it is not already such. Surely not by business as usual. When you think about it, is it not already the case that many publishing scientists actually support themselves by teaching or by development engineering (often in areas only tenuously related to their research)? Maybe the secret of managing productive basic researchers actually lies in keeping them busy in practical activities of immediate payoff while studiously looking the other way as they piggyback research on the resources one supplies.

My bottom line is that, in a steady-state environment, most of us will never be able to support ourselves doing academic basic research in our beloved fields. And with relevance becoming an increasingly dominant consideration in industrial and governmental research labs, the same probably holds true there. Most of us will have to view the frontier investigation for which we trained as a socially valuable variety of recreation to be carried out in the spare time afforded us by the affluent society we make possible through our real-world tasks of educating youth or designing better widgets. But of course! What obvious reason is there for an economy to support an extensive scientific enterprise many of whose members never demonstrate that enterprise's real-world utility? Much as we might wish otherwise, we have no fundamental entitlement save that of spending our spare time and money on the recreation of our choice. ■