COMMENTARY

Conversion of the sceptics

A.R. Gardner-Medwin

SIR George Porter's defence of science driven by curiosity, over that directed to commercial goals, will have boosted the morale of the beleaguered scientific community in Britain. But how much should sceptics as to the value of curiosity-based research be influenced by the example of Faraday's success, or by the systematic work of Comroe and Dripps[1], showing that 41 per cent of key papers leading to a set of clinical advances were not concerned at all with clinical issues? The answer depends critically on how much scientific effort goes into directed and undirected research: information that largely we don't have and that those responsible for decisions may dangerously misjudge.

For simplicity, consolidate the two sides of the debate into two hypotheses HU and HD, according to which the number of advances per funding unit for research that is undirected (U) and directed (D) are in the ratios 2:1 and 1:2. Take the fraction of funding that is undirected to be u. Then the probability that an advance selected at random will prove to be of type U can be readily calculated for each hypothesis:

$P(U{:}HU) = 2u/(u+1)$ (given HU)

$P(U{:}HD) = u/(2-u)$ (given HD)

The theory of evidence[2] shows that the log ratio of these quantities is the correct measure of the *weight of evidence* for HU when examples are type U

$w(U) = \log((4-2u)/(u+1))$

The corresponding weight for examples of type D is the negative quantity

$w(D) = \log((1-0.5u)/(u+1))$

Weights defined in this way add linearly for independent observations. They are the correct increment to $\log(p/(1-p))$, where p is the observer's perceived probability of the correctness of HU. They are thus a good measure of the influence that advances from U and D science should have on policy makers.

The weight of evidence in favour of HU when there are type-U advances (Table 1(b)), is highly dependent on u, the fraction of funding that is undirected. This is extremely important, because u is a parameter about which most of us, scientists and government alike, are very vague. Our first priority should be to clarify it. Consider the risks otherwise. Suppose we are dealing with sceptics who currently believe in HD but are amenable to rational persuasion on the basis of the evidence. If they happen to believe that u is much higher than it really is, then they will grossly underestimate the evidence (by a factor of five if they take u=0.9 instead of u=0.5). What is more, they will grossly overestimate the benefits they would expect to accrue, on their own hypothesis HD, from abolition of undirected research (Table 1(c)). Our efforts to persuade them may have much less effect than they should, simply through ignorance of the value of u rather than any lack of rationality.

Ignorance is a very real factor in the debate. A recent visitor to this college from Whitehall revealed, or so it seemed to us, a surprising lack of appreciation of how science funding actually works. He was not aware that in order to support their research, people must regularly make detailed applications for grants to research councils and the like. He thought that adequate support was generally available through the University Grants Committee (UGC), in the way that perhaps it was for many scientists in the 1960s. Because UGC support at one time represented the purest form of undirected funding, available at the discretion of a Head of Department who would usually see things much the same way as one did oneself, we must perhaps count this 'man from the ministry' as having been, at least before these discussions, a u=0.9 man.

Table 1 Evidence and implications for hypotheses favouring U or D funding

	Fraction of undirected funding (u)				
	.10	.25	.50	.75	.90
(a) $P(U{:}HU)$	.18	.40	.67	.86	.95
$P(U{:}HD)$	.05	.14	.33	.60	.82
(b) $w(U)$	.54	.45	.30	.15	.06
$w(D)$	−.06	−.15	−.30	−.45	−.54
(c) Benefit (u=0:HU)	−9%	−20%	−33%	−43%	−47%
Benefit (u=0:HD)	5%	14%	33%	60%	82%

(a) The conditional probabilities P of a randomly chosen scientific advance proving to have been Type-U, given HU or HD; (b) the weights of evidence (units: log10 or 'bel' (ref.1)) in favour of HU when a success is found to be undirected (w(U)) or directed (w(D)); (c) the benefit (percentage change in success rate) expected from abolishing Type-U funding (setting u= 0), given HU or HD.

Even Comroe and Dripps, in their carefully researched survey, appear to overlook the importance of the relative sums devoted to different types of funding. In their conclusion (quoted also by the House of Lords Select Committee in a recent report[3]) they say that "basic research pays off in terms of key discoveries almost twice as handsomely as other types of research and development". What the data actually showed was that 61 per cent of the discoveries had arisen from basic (that is, mechanism-orientated) research. The advantage in terms of discoveries per pound or dollar will have been more than twice if the fraction of funding devoted to basic reseach was less than about 45 per cent, and less otherwise. The relevant funding statistics are not readily available, but for comparison the breakdown of the principal medical research funding in Britain by source in 1985–1986 was: Medical Research Council (MRC) 16 per cent, Department of Health and Social Security 2 per cent, charities 15 per cent, pharmaceutical industry 66 per cent[3]. It is hard to see how basic research funding in Britain (for which the main source is the MRC) could be as high as 45 per cent.

The terms 'basic', 'non-clinical', 'undirected' and 'curiosity-based' all have different definitions and boundaries. The last two categories are probably the smallest, and their funding fractions are easily overestimated. Within basic research in universities much funding goes on salaries to people who are either not free enough (as someone's assistant) or not temperamentally inclined to pursue their own curiosity-based research. Though the project may originate from a chief investigator's curiosity, or at least the curiosity of some years previously, it may also have been tailored to correspond to what a Research Council is known to favour (that is, directed research). Even project leaders with tenured jobs frequently mortgage their liberty through research contracts or grants, in the manner of Faraday, to the extent that if they take these contracts seriously they can hardly conduct curiosity-based research. The core of truly undirected funding in Britain has probably steadily diminished along with the declining adequacy of UGC funds for research, and is probably at present a small fraction.

A sceptic may be converted by the undermining of his logic as well as the presenting of evidence. Those who support directed funding may base their belief on what seems in general a highly rational principle: when you spend money you ought to know what you will get for it and why it will be of benefit. Scientific success depends on a combination of ideas and facts. On the whole, if you want facts in science you can buy them. Directed funding is the best way of buying them. It is the nature of ideas, however, that you don't know what they are until you have them. You can provide an environment to nurture them and as a funding agency you can solicit them, but you cannot generally direct their production. It is ideas that benefit most from curiosity-based research with flexible funding. The reasons for this are neither very odd nor in the least inconsistent with the British government's monetarist principles. □

1. Comroe, J.H. & Dripps, R.D. *Science* **192**, 105–111 (1976).
2. Good, I.J. *Probability and the Weighing of Evidence* (Charles Griffin, London, 1950).
3. House of Lords Select Committee on Science and Technology "Report on Priorities in Medical Research" (1988).

A.R. Gardner-Medwin is in the Department of Physiology, University College London, Gower Street, London WC1E 6BT, UK.