

## **Night thoughts of a theoretical physicist**

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(an unpublished tribute to John Ziman on his 75<sup>th</sup> birthday, April 2000)

For more than thirty years, I have been able to make physics with delight and enthusiasm. In large measure I owe this privilege to John Ziman's protection and mentoring during my early years in Bristol. We never worked on the same physics, and what I did then was unappreciated for a long time, so it remains a mystery how he could divine that I might have a spark of intellect, and shield this from potentially hostile winds so that it had the chance to grow into a flame.

Mindful of John's transmutation from a physicist to one who seeks to elucidate the complex web of social interactions associated with science, I note another transmutation. Those who administer science in practical ways have changed: from people who saw it as their duty to serve our interests, into members of a coherent profession, not always sympathetic to what we do. This development has ominous aspects, and my aim here is to draw attention to a few of them.

In the 1950s, there was a cartoon showing a collection of girls on a beach. Ignoring a hunk with bulging muscles, the busty bimbos in bikinis clustered admiringly round a weedy little fellow in glasses reading a book on nuclear physics. How we wince at this cameo from those distant days, with its unattractive stereotypes: women as decorations, men with muscles as stupid, glasses as an indicator of nerdy intellectuality, nuclear physics as a route to sexual gratification... I draw particular attention to the picture of science as an activity to be admired for the power it represents and gives. The promise of unlimited cheap energy, and the actuality of the bomb, made it seem that the physics of the nucleus would transform our lives just as the physics of electromagnetism had done (and is still doing). As we all know, neither the fears nor the hopes were realised.

Modern reactions are more complicated, but include a current of instinctive revulsion against science as something that threatens us. This

particular current is not new. Isaiah Berlin<sup>1</sup> has documented a similar one in the late eighteenth-century romantic reaction against science, summed up in Hamann's phrase "The tree of knowledge has destroyed the tree of life". From nowadays, I quote Bryan Appleyard<sup>2</sup>, who when a child was astonished by his father's ability to calculate the volume of water in a water-tower, but "sensed something ominous in this wisdom", and Fay Weldon<sup>3</sup> "We all did science at school. We all know that when our experiments came up 'wrong' they were simply overlooked, ignored. The scientists just can't face the notion of a variable universe. We can." This is silly, of course, but Appleyard and Weldon are not silly people and in part they were motivated by an understandable reaction to a type of science popularisation that Appleyard calls the 'crude ahistorical arrogance' of claims for theories of everything.

It ought not to be necessary any longer to argue for what is good about science, what makes it worth doing. But in these postmodern (or is it postpostmodern?) days it is still true that:

- Science is one of the few activities cutting across nations, cultures, religions - somewhat like sport, but with the crucial difference that co-operation, rather than competition, is strongly built in. In science we usually speak about our foreign colleagues, rather than our foreign competitors. National boundaries are irrelevant. I am indifferent to, and often ignorant of, the nationality of those whose work connects with mine. This is a healthy antidote to newly erupting nationalisms. (To avoid misunderstanding, I emphasize that I am referring to the attitudes of most scientists, and not to journalists and research councils, who - from ignorance or mischief - put excessive stress on the competitive and national aspects of science.)
- Science is a model for the rational and civilised exploration of disagreements, largely without rancour and in a way that leads to progress. This is a healthy antidote to fundamentalisms, now on the rise worldwide.
- From science come inspiring and magical connections between very different things. This observation counters one of our commonest criticisms: that by the reductionist disarticulation of the world into its parts, which are then studied separately, we lose the sense of the whole. My favourite example starts with the question: Why is matter hard? Atoms consist mostly of empty space, after all, so why doesn't matter squash down, with all the electrons collapsing into their lowest quantum energy states near the nuclei? Because this is prevented by the Pauli exclusion principle: no two electrons can be in the same

state. And where does that come from? It could well originate in a property of rotation in three-dimensional space<sup>4</sup>: holding a glass of wine, you can turn it completely twice (that is, through  $720^\circ$ ) and find at the end of this contortion that your arm is untwisted (this does not work for a single turn). I find that ‘two into none’ connection, that totally unexpected association of microscopic hardness with geometry<sup>5</sup>, miraculous.

- And now descending from the sublime to the mundane, science brings economic benefits. Some people, narrow of vision, call this ‘the real world’. There have been reports<sup>6</sup> on physics-based industries showing how profitable they are, relative to others. I will not describe that in detail, but instead will give a small example from my own experience, to show the surprising ways such benefits might accrue. In one of his lovely films, David Attenborough showed insects floating on a sunlit pond, and pointed out their curious shadows: unlike more familiar shadows, these underwater ones have bright edges. The reason is that surface tension bends the water near where the insects float, and the light is sharply focused by these curved surfaces. This prompted a systematic study<sup>7</sup> of bright shadows, including the similar ones cast on the bottoms of rivers by little whirlpools on the surface. In these shadows, the light focuses onto a ring. That was in 1983. The paper was noticed by Michael Gorman, a physicist at Houston. It inspired him to make a plastic lens of unusual shape, whose function is to mimic whirlpools with their ring focusing. He surprised me by announcing that he had patented this construction with the hope of profiting from it. For example, angioplastic surgeons were interested in shining a powerful laser through a tiny version of the lens, at the end of an optical fibre, and with the ring focus bore holes through blocked arteries. (At my time of life, this application is close to my heart.)

Notwithstanding the economic transformations wrought by applied science, it remains true that none of us does fundamental science for the money. (By ‘fundamental’ I mean what is insultingly called ‘curiosity-driven’ research – to be contrasted with the greed-driven variety, I suppose.) Some scientists may be more business minded, but this is always a small part of what drives them. I have always been surprised and grateful to live in a society so civilised as to pay me anything at all to pursue these obsessions in complete freedom. Support for science is a fragile miracle; we cannot expect non-scientists will automatically understand why it should continue. Science is not a natural activity for most people. I would not find it easy to argue the case for supporting me with an unemployed lone parent, or with someone from our recreated beggar class.

Over the decades during which I have been in science, my union, the Association of University Teachers, has always pressed vigorously for higher salaries, and of course I have benefited from their successes. But it is hard for me to support such wage claims with an easy conscience, because they are based on the biased application of relativities. The arguments often run like this: my salary has slipped relative to that of workers in profession A, or is much less than I would get in country B, so I ought get more. But nobody argues that this means the A workers get too much, or points out that there is a country C where scientists get much less than we do, and takes this to imply we are paid too much. There seems no way to establish the absolute value of dreamers (or anybody else for that matter).

Let us assume, however, that it is greater than zero - that is, that fundamental science, pursued without thought of applications, is regarded as worthwhile. Even small science costs money - not much, but the amounts are large in comparison to what individual scientists can afford from their own pockets. In the traditional university system (of course I mean the one I grew up in) small projects were often paid for out of departmental funds. This was possible because we had what came to be called 'the well-found laboratory'. That no longer exists. Departmental funds for research have been cut and cut and cut. There never was much flesh - let alone fat - and now we are well into the bone. So somebody who has a bright or wild idea, and wants to abandon everything else to pursue it, must either be a theorist (we can change course quickly) or else get a grant. This takes time, which destroys a flexibility that the old system allowed.

In spite of these negative indications, the situation is not completely bleak. It is sometimes asserted (for example by the organisation Save British Science, with whose views I usually agree) that modern granting agencies have a built in bias towards 'safe' projects with a well-defined timetable and assured outcome, and against chancy proposals. I must say that my admittedly limited experience is different. I have never used 'chanciness' as an argument against a project and have never heard, on any funding committee, anybody else do so. Nor have my own more speculative projects been rejected for this reason. People can be more sensible than the systems they have to work with.

There is an unfortunate trend in our universities (and indeed throughout the professions) towards greater bureaucracy. Hardly a week passes without my head of department getting a demand for elaborately quantified 'information'; it

is not clear who is being informed or to what worthwhile use the data will be put. He tries hard to protect us - the rank and file - from these demands, but inevitably some of it filters down. How many papers did we publish last year? Itemise the list into twelve categories - yes, twelve! Which are the best ones? How could we contract our group into 25% less space, because the Bursar's formula proves that we have too much. How much time do we spend on research? On teaching? Administering? A senior scientist in what used to be the Royal Signals and Radar establishment at Malvern told me that their management required his day to be broken down into units of six minutes. On the first try, 25% of the laboriously collected entries were found to have been wrongly typed in and after two months there was still no reliable printout of the results. Do the questioners not know that many of our best ideas come at random times: standing in front of students, under the shower, filling in idiotic questionnaires...?

In recent years, universities have acquiesced in having several new layers of bureaucracy imposed on them. One is the Research Assessment (I resist the half-apologetic and self-mocking modifier 'Exercise', carrying the suggestion that the activity is merely a practice run for the real thing). Another is the recent Teaching Quality Assessment (TQA), where 'swat teams' of judges require the preparation of several filing-cabinets-worth of paperwork in case it might be required during the few days of their visit. Those who conduct these investigations are our colleagues, polite, well-meaning, respectable, occasionally distinguished. But I see little if any good in their activities, and much harm. The deputy head of one mathematics department had to retire early as the result of a nervous breakdown caused by the demands of the TQA. Many departments' research planning has degenerated into short-term strategies aimed at 'doing well' in the next assessment. Unforgivably, this has infected the highest levels of academe with the perception that the purpose of intellectual activity is to get high scores in tests – a vulgar quiz-show measure of mental achievement, the very same 'examinitis', that every serious thinker regards with derision when it breaks out among students. Fortunately, powerful and sensible voices<sup>8</sup> begin to advocate radical downsizings of the two assessments.

When William Waldegrave was minister of science, I grumbled to him about the growing bureaucracy of checking-up. I think he appreciated the point, but his response was a bit lame: "It's the spirit of the age: everything must be measured." They - the tormentors, I mean - think this kind of assessment is both

democratic - because it is a way of reporting back to the taxpayer - and scientific - because it is done with numbers.

I was able to give him a delicious example - a masterpiece of false quantification - of how ridiculous it can be in practice. This is from an annual report of the National Physical Laboratory<sup>7, 9</sup>, from the section called “Performance Targets”. Target number three was “Research Milestones”. Everything must be defined, and indeed we have: “Detailed definition of measure: Research milestones are those which are agreed with the customer”. I am not joking. The goal was 0.49 research milestones per scientist per year, to be increased by 3% for each scientist over a four-year period. In the first year, 0.48 research milestones were achieved. A near miss. Must do better. In the second year, though, it was 0.79. Now comes the giveaway: “The comfortable achievement of this target, while pleasing, probably indicates the unsatisfactory nature of this measure. A revised target will be set...”. In successive years, the number of milestones increased, until<sup>10</sup>: “...NPL is making increasing use of project management techniques which encourage the breaking down of programmes into modules, and in which the measurement of success by milestones is *even more significant* than it was at the time when the target was set” [my italics].

I suppose a salary was wasted employing somebody to produce that. It is not only rubbish: it is dishonest. If you doubt this, try to imagine an organisation reporting: “Last year we failed to meet any of our targets.” Of course that would never happen. It is all uncomfortably reminiscent of the old Soviet five-year plans, glossed up by a modern advertising agency: nobody can ever fail - and, as a very British touch, nobody should succeed too well either.

The minister listened quietly, but looked a bit uncomfortable. A week later, I discovered why: he had just presented the National Physical Laboratory with that year’s Price Waterhouse award for the best annual report.

For many of my colleagues, this amounts to harassment. It could be fatal. Successful basic research involves intense concentration, undistracted, over long periods. Newton was asked how he managed to penetrate so deeply into fundamental problems, and replied “by thinking continuously about them”. Even those of us with research positions know how easy it is for prime thinking time to become marginalized. There are so many other legitimate demands - refereeing papers and people, writing talks, etc. Of course we all develop

defensive strategies - into the bin, unread, goes anything from the University Industrial Liaison Officer, all Eurobumf etc.

This threatened and actual degradation of many scientists' working lives seems the unintended outcome of an ideological cocktail whose ingredients are accountability, measurability and a business-based model of efficiency.

It is hard to quarrel with the view that because we are spending public money we ought to be able to justify what we do with it. 'Accountability' is a mantra, spreading through our national life. Simply to utter it is to make any case look unanswerable. But it cannot be right that by a sort of Heisenberg uncertainty principle the justification interferes with the research process itself – and the 'Planck constant' for science (as for creative activity of almost any kind) is pretty small. Yet there is an answer to the accountabilitarians, a single unfashionable word: trust.

The new 'science' of objective measurement of research output seems based on the hope that this can be as precise as crystallography or nuclear magnetic resonance. I doubt this, and in any case do not see how it can replace intuition about the promise of a young scientist or a new idea. Quantitative research assessment is a new profession in a rapid growth phase; it will probably stabilise, but at a size large enough to be a nuisance. On the scale of intellectual respectability, it probably beats astrology, but graphology and mechanised lie-detection spring uncomfortably to mind. With the pretence of precision comes a vocabulary of empty evocations: universities have 'mission statements' declaring their 'commitment' to 'excellence', to 'quality'.

Worst of all is the business efficiency paradigm. I am sure many academics regard this with particular hatred. One manifestation is that we are judged now by how much money we bring into the University in the way of grants, etc. This distorted image of universities as businesses is poisoning relations between administrations and academics. In former times, administrations were small, for the most part invisible, and, in my experience at least, unfailingly obliging when we needed their help. As individuals, university administrators still do try to be helpful. But they are beginning to regard us differently. Academics who do not attract - or even seek - grants are increasingly regarded as a charge on the others - even though, as we all know, such individuals can play a very valuable part in the life of a department. In an unguarded moment, a former registrar at my university referred to those she served as her 'customers'. To administrators, we no longer belong to departments; physics is a 'cost centre'. Am I alone in finding

this a repulsive image, reflecting a grotesque misunderstanding of the nature and meaning of our activities? Universities are not businesses. When they try to act as businesses they are usually not very successful; in my own university there have been several costly failures at profit-making. In fact the proper business of a university, or a department, should not be business at all. What we are paid to ‘produce’ in a physics department is not profits (in the form of grants or sponsorship) but physics.

To avoid confusion, I should declare that I have no objection to scientists or anyone else getting rich from their intellectual or entrepreneurial efforts. Closer links between universities and businesses are welcome too; Bristol University’s collaboration with Hewlett-Packard’s Basic Research Institute for Mathematical Sciences is admired worldwide, and has borne splendid intellectual fruit. Commercialization is obnoxious only when forced on us, when we are told that “Scientific excellence in its own right is not enough”, that we should see “the spread of the enterprise culture across the university”, and that, even if we are dismal failures at moneymaking, we can at least pretend: “if the university could present what it already does in the language of enterprise, it will benefit”<sup>11</sup>.

I do not wish to exaggerate. It is still a wonderful privilege to do science in Britain. It is easy to find the grass greener elsewhere, especially across the Atlantic, but my experience of the hard to summarise (because much more varied) American situation is that they are suffering many of the same problems I describe (it seems that management fads are adopted here just when they have been shown to fail there). There is a trickle of distinguished reverse brain drainers, which could one day exceed the conventional one. An optimistic sign here is the appointment (albeit half-hearted and occasional) of ministers responsible for science. Usually, they have little if any first hand knowledge of what we do, and in any case this is the British way: appoint an amateur. But at least one minister did write some remarkably good sense about the fundamental aims of science. I hope some politician will soon have the courage and vision to reverse the futilities being imposed on us – futile, because repeated reorganizations that follow each other faster than the response time of the academic system can result only in innovation exhaustion.

Finally, here is an unfashionable thought to annoy those who would continue to ‘reform’ our institutions of higher learning. It was inspired by a recent biography<sup>12</sup> of the mathematician Ramanujan. While in his creative prime,

Ramanujan lacked employment. According to a friend who helped him get work in the port office in Madras, what he needed was a job without too many duties, that would give him *leisure*. The biographer points out that he was using that word in a different sense from today's. To us, it implies something trivial: 'freedom from' work. But in those days it carried the positive connotation of 'freedom to' - in his case, create mathematics. It is leisure in this sense that we need to reclaim, and then preserve, in our universities.

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