Technological speculations and science

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ABSTRACT

Scientific advance is driven more by technological advance than by any other factor. But there is a lack of opportunities to publish ideas about new technology that could advance understanding of science. In part this is because technological speculation can be unlimited, and so is worthless, without physical proof that the idea can work. But new technological ideas rarely arise in a single mind, or discipline, so communication of incomplete technological ideas has a valuable place in their development. This Journal embraces not just scientific hypotheses but technological ones as well, to help spread half-formed technological ideas into the community where they can be finished as concepts and turned into prototypes.

TEXT

What makes great breakthroughs in the life sciences? I believe it is not the steady accumulation of facts and data, although this is what nearly all of us are doing. It is not the brilliant insights into the nature of living processes, although that is what prizes are given for. I believe it is technologists.

Take the history of molecular biology. The pivotal year was 1953, but like any pivot this was in the middle not at one end, and the revolution really started in the 1920s. Reading any textbook on the chemistry of life published 100 years ago shows that scientists thought of biochemistry in a basically different way from how we think of it today. The materials of life were characterised by bulk chemical properties, and their properties were to be understood in terms of those bulk properties, such as overall charge, composition (which was defined in terms of ratios of components, not distinct molecular formulae) and so on. Thus proteins were colloids, whose properties could be understood in the same way as other colloids such as smoke, clay and colloidal gold. For example:

"The precipitation of one colloid by another has been shown to be connected with the electrical condition of the respective substances. An electro-positive colloid will precipitate an electro-negative colloid and vice versa. … The coagulation of 'toxins' by 'precipitins' in serum is based on [this] property." [1]

The same book mentions nucleic acid only once, as the compositional component that distinguishes 'nucleo-protein' – i.e. the protein in the nucleus – from 'albumin' – i.e. the protein in the cytoplasm.

We now look on this as a bit quaint, but that is because we are used to thinking of proteins as distinct molecules with a defined shape, and it is the shape of 'toxins' and 'precipitins' that allows (in modern terminology) antibodies to bind specifically to antigens. This change in ways of thinking was brought about not by endless analysis of the amino acid composition of proteins, classifying them according to their content of 'hexone bases' (i.e. 6-carbon amino acids) and so on [1], but by the development of the ultracentrifuge [2] and later of gel filtration which showed that individual proteins had a distinct molecular weight, and hence were not an aggregated material analogous to colloidal clays or metals but individual molecules like the amino acids from which they were composed. The concept of a genetic code for proteins makes no sense unless you realise that

proteins have a distinct structure. Its elucidation would also have been almost impossible without radioisotope tracers, again a technology developed in physics and applied to biology. Now we are familiar with the idea of 'circuits' of gene control and of talking or protein activation and deactivation as if the logic gates of the cell are flickering on and off like silicon in our phones. But both the logic and the mathematical tools to look at life in this way were available to Newton. What was missing was the realization that life was organised as discrete interacting units, which came from new technologies for looking at life.

If hardware plays such a role in biology, why is there not a Nature Hardware[1] or a section in PNAS called engineering? Because of a basic difference between science and technology.

Science is based on building models of how the world works and then testing them. Thus some science 'just' accumulates data (the metabolic map, the genome sequence), other science uses such data to build a model of the world, still other tests the model (and the implicit model in the original data-gathering strategy) with new experiments. Each new experiment, each piece of data, is potentially valuable.

By contrast, technology speculates that something can be done, and then tries it. Genuine breakthroughs in technology (as opposed to incremental innovation) are the reverse of the usual logic of science. For science, a good hypothesis is true until proven false. A single counter-example could disprove it (although rarely is it that simple), and then it is false for all time – no new experiments can bring back phlogiston or epicycles. For technology, you can speculate anything, but your speculations are assumed false until you have proved them true. Just one working prototype proves a technological speculation, and then it is true for all time: no-one can now say that building a heavier-than-air flying machine or a stable bicycle or a stone building over 150 m tall is impossible, because examples exist. This is why patents require worked examples to be valid.

But the downside to this is that there is no limit at all on technological speculation, even within the bounds of physics and plausibility. So there is no point publishing technological speculations (it is argued) because the valuable part of technology is making that first prototype, and once you have done that the importance for science is what you have done with it. Building a machine that can sequence a gene in minutes is useful because of the genes it can sequence.

But this is the same view that says there is no point publishing new hypotheses until you have a book-full of data to back it up. The problem with it is that, more than scientific ideas, new technological ideas rarely spring from a single mind or a single discipline. Genome-scale sequencing technology came from a convergence of chemistry, biochemistry, fluidics engineering and control IT. MRI and CT scanners are based on sophisticated physics, not medicine, but the medicine is central to their invention because that defines what they should do (and provides test examples). Collaboration is critical, but how can a collaborator know that you have a good idea if that idea is never published?

This Journal does not subscribe to the idea that only fully tested scientific or technological ideas are worth publishing. Half-worked out ideas can be accelerated and applied through public discussion, but that will only happen if they are made public. This applies as much, maybe even more, to technology as to science.

So this Journal embraces papers not just on new scientific hypotheses, but also new technological ones. Because science is advanced by technology (and technology by scientific knowledge), getting 'technological hypotheses' into the public domain is an important part of scientific progress. Bring out your ideas for new ways of finding out things about life.

1 There is a Nature Methods, which comes close

But … remember that technological ideas are not valuable unless they are a significant step along the way to a prototype. Speculation that ‘it would be useful if…’ is of very limited value, as it does not even indicate why the speculated idea could be possible. So a technology hypothesis must identify a major barrier, ideally the major barrier, to making that prototype, and describing a way round it. For example, a 10 nm resolution X-ray hologram machine would revolutionize cell biology, but just saying so does not get us any further forward. Cellular holograms need an X-ray laser[2]: the one big reason why we cannot make a 10 nm hologram of a cell is lack of an X-ray laser, not (say) lack of X-ray film. If you do not have a solution to that problem, then you do not have a better hypothesis than I do, and we will not publish it.

So, bring on your technological hypotheses. Above all, talk to your engineer, physicist or chemist colleagues about the big problems of life science and how you would solve them with new technology, and if you come up with a clever, convincing, powerful new idea that you have nearly all the pieces for, then we may be able to help you find the missing piece.

References

[1] G.J. Fowler, An introduction to bacteriological and enzyme chemistry, Edward Arnold, London (1911) p. 10–1.

[2] T. Svedberg and K.O. Pedersen, The ultracentrifuge, Clarendon Press, Oxford (1940).

2Or do they? Current holograms need a coherent photon source, but this need not be a laser.