Physics is dead, long live physics!

It would seem unlikely that any part of science, including physics, could ever come to something like an 'end' — a point beyond which its subject matter would be more or less exhausted. It's difficult to think of an historical example of any 'dead' science; even fields as well-worn as classical mechanics continue to elicit new surprises each year. Even so, talk of the 'end of physics' was precisely what I heard in a recent dinner conversation between two young physicists, who were chewing over views they'd heard expressed by a pair of rather famous older physicists.

Physics is dead, a Nobel-prize winner had asserted, because most of the relatively easy problems have been solved, and significant further progress now often demands extremely complex and expensive apparatus — the Large Hadron Collider at CERN being the most recent example. Meanwhile, in other areas of physics — especially string theory and perhaps, to some extent, cosmology — we seem to have reached an era in which theory is virtually unconstrained by experiment. There remains, of course, the ever-vibrant area of condensed-matter physics, especially rich as a source of new devices — yet this might increasingly be seen, this eminent physicist suggested, as a branch of materials science.

In the conversation, however, the other physicist countered that if physics is dead, or at least in decline, then the methodology of physics is, by contrast, thriving. Indeed, perhaps no trend in modern science has been more pronounced than the flow of physicists into areas of science traditionally having little to do with physics, ranging from the study of social networks and financial markets to neuroscience and molecular biology. And the reasons for this trend seem quite natural.

Indeed, many key problems in the social sciences, in biology and elsewhere are being attacked seriously for the first time ever, in part because of unprecedented technologies for the gathering of data, and of course the utility of computation as an investigative tool. And physicists, it seems, are naturally poised to help with their own distinctly successful view of how to do science.

As one recent example, take the problem of understanding and managing traffic flow at complex intersections. Curiously, it was two physicists, James Lighthill and Gerald Whitham, who developed the first fluid model for traffic, way back in 1955, in a paper entitled "On Kinematic Waves: II. A Theory of Traffic Flow on Long Crowded Roads", published in *Proceedings of the Royal Society, Mathematical and Physical Science*. Their work, still relevant today, established a mathematical view of the dynamics of traffic congestion fronts based on a continuity equation describing the conservation of vehicles, coupled with a semi-empirical relationship relating vehicle flow and density.

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In rough terms, their work suggests two characteristic speeds that strongly influence the flow of traffic on, say, a city street: first, the speed limit, at which patterns in traffic ordinarily flow forwards; and second, a backward speed, about -15 km h^{-1}, at which a front of jammed traffic will flow back upstream.

More recently, researchers — notably Dirk Helbing and colleagues at the University of Dresden in Germany — have built on this work to explore traffic flow in road networks, which requires the extension of one-dimensional models to situations in which traffic flows merge or intersect. Of particular interest is the problem of optimizing the timing of traffic lights in urban road networks, and especially coordinating their timing, so as to produce more efficient flows.

To do so effectively clearly means having lights that vary their timing in response to changing traffic flows. But, of course, if fluctuations in traffic affect the timing of lights, which in turn alters the flow of traffic, one has a delicate self-consistent problem to manage. Yet Helbing and colleagues have demonstrated in simulations (S. Lämmer & D. Helbing, arxiv:0802.0403v2; 2008) that a decentralized control algorithm, based on simple heuristics for the timing of each light, leads to close to optimal operation for most traffic conditions. Their engineered solution achieves a significant reduction in overall travel times, and a small variation in waiting times, so that traffic flow, while strictly unpredictable, nevertheless feels fairly regular.

It's hard to argue against this being physics, obviously with a strong engineering flavour. The objects interacting may be vehicles and traffic lights, yet the outcome depends strongly on collective dynamics that emerge in a non-trivial way from the underlying interactions. Helbing may hold a position as 'Chair of Sociology' in particular of 'Modeling and Simulation', but what his group is doing, by all accounts, is physics, even if their inspiration for this work came in part from familiarity with self-organized oscillations observed in the flow of pedestrians at narrow passages or bottlenecks.

The philosopher of science Thomas Kuhn was convinced that it's actually impossible to pin down what really constitutes the scientific method, and that good ways of solving scientific problems get passed down by way of example. In this regard, surely one of the principal lessons absorbed by all physicists is the good sense of starting simple, exploring the crudest plausible models first, and developing progressively more complex models only when driven by a demonstrated inability to explain the data.

Perhaps this is the greatest contribution physics can make to the rest of science.

None of this is to say, of course, that physics in more traditional areas really is dead, or that phenomena in particle physics or condensed matter won't offer rich challenges for the foreseeable future and beyond. Yet a case can be made that the scope for achievement is much broader outside of these areas than in, and that the future of physics really may lie mostly outside of physics.

Mark Buchanan