The changing nature of scientific knowledge

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The motto of the Royal Society is "Nullius in Verba", which roughly translates as "Take nobody's word for it". This encapsulates a certain conception of the scientist that finds its philosophical expression in *empiricism*. The ideal scientist is an individual who has performed all the relevant experiments or observations himself (or herself), depending in no way on the reports of others. Any important result achieved by another scientist must be replicated so that the scientist sees the evidence for herself. The scientist is therefore able rationally to assess the likely truth of a theory against this evidence, without depending on other scientists. Science for the Royal Society was, nonetheless, a social activity. But the sharing of ideas is not the sharing of evidence or reasons. To *justify* one's belief in a theory, one needs to see the evidence oneself. And so the meetings of the Society centred on the performing of experiments that all could observe and participate in.

Modern science departs radically from this 'ideal' in several ways.

- Experiments can be huge, costly exercises. It is often simply not feasible to replicate independently the results of such experiments. The scientific community has to take on trust the results of, for example, the LHC at CERN or the data collected by the Hubble telescope, and so forth. Independent verification is not possible.
- Modern science is highly inter-dependent. A evolutionary palaeontologist will need to know the age of rocks in which a fossil is found. That geological information will depend on radiometric dating which in turn depends on theories in nuclear physics. The palaeontologist just does not have the expertise let alone the resources to verify those physical theories for herself. The palaeontologist must *accept* the reliability of the radiometric methods.
- Modern science is often very collaborative. Some research projects have hundreds of scientists participating. Collaborative projects of any size, especially interdisciplinary projects, are made up of scientists with differing expertises. So one participant cannot be expected to be able to evaluate the contribution of every other participant. Nonetheless, the research they produce is presented as the work of all collectively, often published in papers with dozens of authors.
- Early science employed only naked-eye observation, but then science began to rely upon instruments. Once scientists would construct their own instruments, for example grinding their own telescope lenses. But nowadays most laboratory equipment is highly sophisticated and must be manufactured by specialist firms. And so scientists are dependent on the designers and manufacturers of their equipment. While much equipment can be calibrated and checked for reliability, this will not always be possible, especially for bespoke equipment used for unique experimental setups.
- Not only does much science use sophisticated machinery, increasingly that machinery is replacing the scientist. Not only does the equipment record the basic data, but it will analyse it and publish it (e.g. on the internet). Furthermore robot scientists have been constructed that can devise hypotheses to be tested and then design and carry out the experiments to test them. Scientific knowledge is being created with almost no human input.

How should these changes in the organisation of science change our image of scientific knowledge? Do they call our claims to scientific knowledge into question? Do they call for a radical rethink of the empiricist paradigm of how knowledge must be produced?