Dynamics of water interacting with biomolecules

Groot, C.C.M.

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Appendix: The value of science

Science: The intellectual and practical activity encompassing the systematic study of the structure and behaviour of the physical and natural world through observation and experiment.

the Oxford dictionary

Science, simply put, is the systematic study of the natural world. The foremost task of a scientist is therefore to study, i.e., to acquire knowledge towards a more comprehensive understanding of the natural world. Around the world, people devote a lot of time and resources to scientific projects, building giant observatories, installing particle accelerators, gathering large groups of study participants and even sending experiments to space. What drives this quest for knowledge? For many scientists, it is a sense of fascination: understanding the complexity of nature, be it in the physical or social domain, is the primary goal. It is the yearning to know more, and the satisfaction that comes with solving the next puzzle.

At the same time, the generation of knowledge often has consequences. New insights and technologies can impact society in many ways[1,2]. The way most people live nowadays is heavily influenced by discoveries in the past. Consider for example the discovery of electricity by Michael Faraday in 1820, now essential to any modern household, and the realization of Louis Pasteur in the 1860's that many diseases are caused by microorganisms, which saved millions of lives ever since. Less benign examples also exist: the invention of the atomic bomb for instance provided the world with such an effective weapon that it changed the entire political landscape. Even though only few discoveries have such far-reaching implications, it makes clear that scientific findings can have a great impact on society.

With this in mind, perhaps, the term "valorization" has entered the scientific world. That is, the creation of value from knowledge, by transferring this knowledge into products, services or processes. The term was first coined by public policy makers wishing to see return on their investments: in return for funding, scientists across all disciplines are expected to contribute to societal benefits[3]. Scientific advance does indeed hold promise to provide solutions to societal problems. We can for example foresee answers towards more efficient and cheaper clean energy sources, more sustainable food production and better treatment of diseases. On a global scale, the major societal objectives have been formulated in the UN Millenium Development Goals, and science and technology are expected to be crucial factors in reaching these goals[1,4]. On a national level, scientific knowledge has been shown to stimulate the economy, thereby enhancing the standard of living. The economist Robert Solow (winner of the Nobel prize in 1987) and later colleagues identified technological progress as the main factor of economic growth[5,6]. It is hard to estimate how much science, as a driver of technological progress, contributes to growth, but economists estimate a substantial 20%-60% return on investments in science[7,8].

In my eyes, the fact that scientific insights can be used to improve people's lives makes science very valuable. The term valorization emphasizes this fact, and encourages scientists to think about the consequences and possible applications of their results.

At the same time, in attempts to stimulate valorization, scientists are increasingly evaluated on societal relevance[9−11]. This creates some complications. Firstly, the very nature of science, as the study of the unknown, prevents a reliable prediction of the long-term societal impact of a study, especially in the case of basic research. A famous example is the experiments by Heinrich Hertz on radio waves. These experiments are at the base of many of the modern communication technologies, but Hertz himself remarked[12]: "It's of no use whatsoever[...] this is just an experiment that proves Maestro Maxwell was right - we just have these mysterious electromagnetic waves that we cannot see with the naked eye. But they are there." As a result of this unpredictability, scientists conducting basic research have a harder time convincing funding boards about the merits of their research, and budget is moving from basic science to applied science, and from creative ideas to short-term low-risk projects.[a] The question is whether this approach will in the end lead to the most benefit for society. Applied research may have the most impact on the short term, but radically new approaches to societal problems will likely not emerge.

A second complication is how to evaluate societal impact. What is beneficial for the local economy, such as partnerships with private organizations and the creation of patents, is not necessarily beneficial for the larger society, or even for science itself. From an economic viewpoint, for instance, it is best to develop medicines targeted to the demands of the rich, which does not help the societal aim of eradicating diseases that primarily affect the poor[1]. From the same viewpoint it is vital to protect generated knowledge with patents, such that a competitive position on the market can be maintained. Patents and other intellectual property (IP) rights, however, can also hinder innovation, as patents might be too expensive for new players to use the knowledge. It can furthermore clash with the openness and knowledge transfer that is so crucial for scientific advancement[1,13]. In recent years, absurd situations occurred where scientists working together with private organizations are expected to investigate materials or devices without knowing what they are made of, in light of IP rights. This likely does not help science nor the private organizations involved. Too much focus on economic indicators of valorization might thus lead to the opposite of the desired effect.

So we find that stimulating and evaluating valorization is not so simple.

[a] This trend is also driven by the fact that discoveries in basic science usually don't directly benefit the investor, who takes the financial risk, but benefit all, as findings travel with internet-speed across the world[7].

Currently, valorization mechanisms are to let scientists write about the future use of their future knowledge, and to list performance indicators like the amount of collaborations inside and outside academia, public lectures, outreach activities, patents, and received prizes. It remains to be seen whether the scientists that are most excellent on paper are actually the ones that turn out to find the answers that contribute most to society. We must especially be careful not to focus too much on the particular performance indicator of high-impact papers. In the current scientific climate of extreme competition, a high-impact paper can make or break a scientist's career. To publish in a high-impact journal, an exciting and novel discovery is needed, while attempts to thoroughly reproduce studies often end up in less highly regarded journals. The number of irreproducable studies is consequently alarmingly high[14]. It would be tragic if the way we try to stimulate science and its societal impact led to the loss of science itself, as in the systematic study of the natural world, and the search for the truth, or as close to it as we can get[13]. Without proper science, we cannot expect benefits for society at all.

History has shown us enough examples of scientific discoveries with great impact and many benefits for society. Let us therefore reward rigorous science, look critically beyond the numbers at real quality and societal impact, and continue to reap the benefits.

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