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Author: SNYDER, BRIAN

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BRIAN SNYDER

Apollonius of Perga was a Greek mathematician who worked at the museum of Alexandria shortly after its founding around 280 BCE. The museum was the world's first center of pure learning and research, a place where mathematicians and philosophers could work freely on projects of their own interest, without the requirement that they apply their science to serve the needs of the kings who supported them. There Apollonius worked out the mathematics of conic sections—computations that, as you might imagine, meant almost nothing to the people of ancient Greece and Egypt. In fact, Apollonius's work did not hold much relevance for anyone for more than 1800 years. It was not until the beginning of the 17th century that his work found perhaps its first applications. Johannes Kepler used Apollonius's mathematics to demonstrate that the orbits of the planets were not circular, but elliptical—the shape you get when you slice through one of Apollonius's cones. Kepler's work was later used by Isaac Newton to demonstrate that gravity held the planets in orbit around the sun.

Apollonius is the classic example of a basic scientist. Perhaps he thought that his work was important, or hoped that it would some day find an application, but he could not have known exactly how important his work would be to science and humanity. Apollonius's story demonstrates that science, no matter how pure, is fundamentally important because of its collaborative and progressive nature, a lesson that is particularly important for basic biology.

Biology is perhaps the most obviously applicable of the sciences; medicine and agriculture, two of the professions responsible for sustaining human life on the planet, are simply applied biology. It is odd, then, that basic biological research, especially research in ecology and evolution, is seen not as a practical endeavor but as a curiosity, a pursuit that may explain life's diversity but will not improve its quality. As a result, basic biology is funded primarily through the roughly $600 million budget of the Biological Sciences Directorate of the National Science Foundation (NSF), while medical biology is funded through the $28.5 billion budget of the National Institutes of Health (NIH). Although more than half a billion dollars may seem like a lot of money, it makes up less than one-half of one percent of the total US research and development budget. For comparison with the total $2.7 trillion federal budget, think of it this way: For every $100 you pay in taxes, little more than two cents goes toward NSF-funded biology research.

In fiscal year (FY) 2006, the biology directorate funded just 14 percent of the research grant applications it received. The average annual award size was $190,670. Compare this with figures from the NIH. In 2006 the average NIH research grant was worth about $428,000 per year, and the success rate for grant applicants has averaged 29 percent over the past decade.

The problem with the poor NSF biology funding is that basic biological research lays the foundation for applied biomedical, agricultural, and environmental research. We could not understand or prepare for the emergence of new infectious diseases such as the avian flu virus without the basic research of Charles Darwin. Yet if Darwin were working today, who would fund him? It seems unlikely that the NIH would be interested in Darwin's voyage on the *Beagle*. The $28 billion the NIH spends annually funds basic organismal biology only if it has a significant medical component, and it is doubtful that grant proposal reviewers at NIH would see Darwin's work as relating to public health, although his work would eventually lead to great medical advances. Even today, when the links between evolution and human health are well known, the NIH funds virtually no evolutionary biology. Instead, Darwin would have been forced to compete for a piece of the much smaller NSF pie.

For a more recent example of the applicability of basic biology, take the work of Nobel Prize winner Stanley Prusiner, whose discovery of prions was supported by both the NIH and the NSF (Prusiner 1982). His work was both groundbreaking and extremely risky, and without it we could not understand, and thus could not respond to, mad cow disease. The NSF spent about $163,000 in the late 1970s—worth roughly a half-million dollars in 2006—to support Prusiner's research. How many people are alive today because we made this investment and know how to detect and prevent the spread of mad cow disease?

Or take the work of Rita Colwell. From the early 1970s to the mid 1990s, the NSF funded Colwell's work on *Vibrio cholerae*, the organism that causes cholera. Among the several hundred scientific papers that have emerged from this funding are several that showed *V. cholerae* is commensal with copepods. This discovery allowed Colwell and her collaborators to develop a simple method for filtering water that reduced the incidence of cholera in villages in Bangladesh (Colwell et al. 2003).

The work of Colwell and Prusiner provides two of the more obvious examples of the utility of basic biology, but the

Brian Snyder (e-mail: snyderb@uga.edu) is with the Institute of Ecology, University of Georgia, Athens, GA 30602.

work of Thomas Brock and Hudson Freeze, also supported by the NSF, is perhaps the most fitting analogy to Apollonius of Perga. In 1969, Brock and Freeze found the bacterium *Thermus aquaticus* in the geysers of Yellowstone National Park (Brock and Freeze 1969). Within two decades of their discovery, the enzyme Taq polymerase had been extracted from *Thermus aquaticus,* allowing for the development and widespread application of the polymerase chain reaction (PCR). The impact of their discovery has been critical for progress throughout biology over the past several decades, leading to literally thousands of advances in medicine and agriculture. Perhaps Brock and Freeze knew that their work was important and that it would someday find an application, but they could not have known that it would revolutionize biology and help to launch the field of biotechnology.

In 2002, Congress passed a bipartisan bill that called for the doubling of the NSF's budget over the next 5 years. This funding, however, has not materialized. More recently, President Bush proposed the American Competitiveness Initiative (ACI), which again called for a doubling of the NSF's budget, this time over the next 10 years. Overall, the ACI is a laudable plan that recognizes the importance of research to economic growth. Nonetheless, biologists should be wary of this new promise. Biologists should be skeptical not just because similar proposals have failed in the past but also because the ACI is explicitly directed at the physical sciences. Early versions of the FY 2007 NSF budget even restricted the NSF's budget increase to physical sciences (Knezo 2006).

Scientists should therefore press members of Congress for something specific and achievable: the doubling of the NSF's biology directorate budget over the next five years. In the FY 2008 budget, the NSF's request to Congress for the biology directorate's budget was $633 million, a 4.1 percent increase over the Bush administration's request. To double over the next five years, the NSF's biology budget needs to increase by about 15 percent every year. This amounts to about a $100 million increase a year, a relatively small investment that, as the ACI argues, will pay for itself many times over.

This doubling of the NSF budget should be used to increase the funding rate of biology grants from 14 percent in FY 2006 to 25 or 30 percent, a rate similar to that at the NIH. Simultaneously, the biology directorate should increase the mean annual award size from $190,670 to at least $200,000. Both of these improvements can be made by doubling the biology budget from $581 million in FY 2006 to $1.1 billion in FY 2011. The biology directorate funded 803 new research grants in FY 2006, each with an average duration of three years and a mean annual size of $190,670. This works out to about $458 million per year in research grants. If the biology directorate were to fund 27 percent of the 5700 research grant applications it receives each year, each at a mean size of $200,000, it would cost the agency about $923 million per year, well within the $1.1 billion budget of a newly doubled directorate.

Policymakers have shown that they understand the importance of basic science to technological and economic development. Biologists simply need to remind them that basic biological research is the foundation on which the innovation of the 21st century depends.

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