BioScience Advance Access published February 6, 2014

Oddball Science: Why Studies of Unusual Evolutionary Phenomena Are Crucial

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Concerns about the US budget deficit are pushing government research funding toward utilitarian and translational research at the expense of basic science (Hand et al. 2013). Science funding decisions are increasingly at risk of becoming politicized, and reductions in basic science funding are often justified as eliminating wasteful government spending. Indeed, critics have named several government-funded basic research projects as examples of waste (e.g., Fahrenthold 2013). Recent examples include studies on duck penises, shrimp running on a treadmill, robotic squirrels, and snail sex. The criticized programs are typically studies of organisms with unusual morphologies or behaviors that have no obvious application to society.

The appeal of such criticism is obvious; at first glance, studies of odd evolutionary topics seem frivolous, even wasteful, especially in tough economic times and when compared with applied science intended to cure disease, develop renewable energy, or improve agriculture. The temptation to argue that the federal government should fund only science with a foreseeable benefit is understandable, especially because guidelines of the National Science Foundation (NSF) require reporting the economic impacts of government-funded research in all fields. Some biology researchers have even suggested—misguidedly, in our opinion—that their field should address the interface between basic and applied science, with a focus on projects that address an applied challenge (Cooke 2011, Aarssen 2013). Furthermore, Aarssen (2013) argued that "university research—with no particular societal benefit in mind—has largely run its course" (p. 417).

The problem with this view is that it assumes that human innovation arises in a logical fashion from planned research. History says otherwise: Innovations often arise from unlikely sources. This phenomenon was recognized last year with the establishment of the Golden Goose Awards for projects that may sound odd but that produce significant—usually unforeseen—health or economic benefits (Underwood 2012). Although seeking out projects that are likely to lead to applications may be a good strategy for securing funding, we maintain that reducing our ability to creatively examine unique biological phenomena will ultimately harm not only education and health but also the ability to innovate—a major driver of the global economy.

The study of organisms typically centers on evolutionary innovations—the biological structures and phenomena that enable new functions or behaviors. These adaptations are often surprising and may seem bizarre, but they are the product of over 3 billion years of evolution and are often associated with the successful exploitation of new habitats. Studies of these seemingly oddball adaptations have jumpstarted myriad technological applications. They began, however, as basic scientific questions. Here, we highlight some examples that should be useful for anyone defending funding for basic biological research.

Evolutionary innovation and technology

The Biomimicry Institute has compiled over 2000 examples of technologies inspired by evolutionary innovations, including more-efficient solar panels, insulated glass, and medical and industrial adhesives. Others have military applications, such as a superior personal armor based on the structural properties of mantis shrimp appendages, invisibility technology based on studies of structural color in insects, and miniaturized robots that mimic animal locomotion. Geckskin is a new reusable, glue-free adhesive pad that can hold up to 700 pounds adhering to a smooth surface and has myriad applications. It came from decades of basic research on the anatomy and function of gecko toepads, which are covered with millions of soft hairs that conform to surfaces and allow the strong adhesion that permits geckos to walk upside down. Only recently have companies begun to realize the potential commercial benefits of gecko-like adhesives. Innovations are always created on a foundation of basic science, but they are not always created quickly, nor are they obvious at first glance. The hundreds of studies of geckos before the creation of Geckskin enabled its developers to test ideas and prototypes efficiently.

Perhaps the best-known example of a successful technological application based on basic research on an odd organism is the widespread use of the enzyme *Taq* polymerase to make *in vitro* DNA replication more efficient. *Taq* polymerase was discovered in a study on the distribution of photosynthetic organisms along a thermal gradient in Yellowstone National Park. The researchers sought to examine how unusual microorganisms could thrive in inhospitable habitats (Brock 1997). The first results were published in 1967, a full two decades before an application was developed. Much of modern molecular biology is based on the ability to efficiently replicate DNA *in vitro* using PCR (polymerase chain reaction) technology, which relies on *Taq* polymerase. This innovation has brought vast benefits to medicine, industrial agriculture, and even the criminal justice system.

Evolutionary innovation and medicine

Many drugs have been developed as a result of basic science in which the chemicals produced by different organisms are examined. For example, a promising new diabetes drug (exenatide) was based on studies of the composition of Gila monster venom.

Many evolutionary innovations mimic complex human diseases for which there is no suitable laboratory model (Albertson et al. 2008), such as retinal degeneration and albinism in blind cavefish and reduced bone mineral density in Antarctic icefish. These and other organisms provide a rich source of variation that can help researchers understand human disease. Furthermore, recent data suggest that specified genes implicated in human disease are modified during evolution (e.g., in changes in the stature of domesticated breeds of dog and in the reduction of armor plates seen in many freshwater sticklebacks). The study of evolutionary innovations in nontraditional animal models can therefore be directly relevant to human health. Even the study of duck penises that was recently highlighted as wasteful spending (Brennan 2013, Coburn 2013) has now been discussed as improving the understanding of the developmental cascade that results in hypospadias, a common penis malformation in humans (Zimmer 2013). Moreover, the general public readily understands studies of unusual organisms, which is both a weakness and a strength. It is perhaps one of the reasons for which these studies are often criticized by nonscientists in a political context, but the abundance of organismal biology science stories reported in the news shows that the studies have mass appeal. This suggests that they can play a role in education. It is generally important to support the public's engagement with science, especially in the United States, where only 40 percent of the public agrees that organisms have evolved through natural processes (*www.data360.org/graph_group.aspx?Graph_Group_Id=286*).

Evolutionary innovation and investing in the future

If basic science has economic benefits, why not leave funding to the private sector? The problem with this view is that private investors typically seek a 2–3-year return on their investments, whereas basic research may continue for decades before economic gains occur. There is no guarantee that any one particular basic science research project will translate into a direct application. This unpredictability underscores the need for a long-term commitment, which states and the federal government are best suited to fulfill. Scientific innovations arise from a mix of curiosity, creativity, and knowledge, and the connection between basic and applied science is a network of knowledge that builds over time to generate life-changing ideas. However, according to the NSF, the proportion of grant applications funded for organismal biology—through the Division of Integrative and Organismal Systems—declined from 28 to 17 percent between 2001 and 2010, with some programs reaching as low as 10 percent. The number of proposals submitted has increased by 43 percent during the same time period, but the overall budget has remained basically unchanged after accounting for inflation (in the Directorate for Biological Sciences, it has gone from $511.14 million in 2001 to $678.93 million in 2013, which is equivalent to $514.83 million in 2001 dollars). This means that many young scientists with excellent research ideas will be unable to pursue them.

The inspiration and understanding gained from studying the basic biology of organisms informs biological questions at every level. Without the funding necessary to continue the pursuit of basic knowledge about oddities in organismal and evolutionary biology, the economy will surely lose its ability to capitalize on nature's unparalleled ability to innovate.

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doi:10.1093/biosci/bit039