

Mountains from Molehills: The Implications of Funding General Research

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Twenty short years ago, humans vaguely understood the physiology of their own brain. However, one man's interest in songbirds led to revolutionary ideas about not only avian brain structure and function, but of all vertebrates alike. This man, Fernando Nottebohm, was studying song learning in adult songbirds, and discovered that neurons were being regenerated in several areas of the avian brain during adult years. The implications of such findings were tremendous, and have led to new medical treatments for humans, in addition to contributing to the Theory of Memory (Eisenstein, 2004; Gordon, 2010). Basic research into seemingly general topics, or research that does not aim to find an answer to a specific question utilizing few variables (e.g. exploration of song learning in birds), is a fundamental pillar in the construction of an ever-improving human civilization. Allowing intellectuals the chance to exploit their abilities and knowledge through creative and constructive research inevitably reveals answers to questions that will benefit society either indirectly or immediately, by influencing human practice and thought. Given enough time, the influence of basic research can thread its way into even those who are most disconnected from the academic world, by creating an education system based upon critical thinking, analysis, and evidence. Furthermore, improved education and regular scientific exploration favor a strong economy through reformed healthcare and living conditions. The answers that basic research can reveal have contributed to the ability of humans to globally unite and quickly advance in technology and knowledge of the universe. A country that depends on generalized research can improve its system of education by indirectly influencing teachers and students and may produce discoveries that contribute to the successful future of human society.

Knowledge obtained through general research can be inspirational, and over an appreciable amount of time may improve education and the educational system by creating more insightful individuals that view their environment critically and analytically. Each area of America's elementary education system is based upon a textbook and a list of required objectives, all the while significantly lacking the intuitive and inspiring element of scientific creativity and inquiry. Not until college do most students experience the freedom of theoretic thought, and if they choose to avoid the theoretical sciences during college (e.g. biology, chemistry, physics), their life may proceed completely devoid of these experiences. Just as educational researcher Fred. N. Kerlinger stated in 1977, ideas taught from "theoretical explanations and empirical testing of theory" appeal to students more than words that must be taken for granted. Teaching from current research also fosters an atmosphere of "critical inquiry," which will influence both the teacher and student to think analytically about the topic under observation and apply that method of thought to their lives (Kerlinger, 1977). In institutions of higher learning, teaching concepts from classical research papers rather than textbooks compiled with generalized ideas is commonplace, especially in the physical sciences, and should be implemented in primary schools as well to produce analytical students who may prove to be more enthusiastic and motivated about their field of study.

As illustrated by Alberts in his paper on scientific education, elementary and high school education in the United States is falling behind that of other countries, and is correlated with a plateau in federal research funding from 1996 to the present (Alberts, 2009; Hather et al., 2010). A country that supports and inspires general research will generate a citizen population that supports these efforts. This influence will then transfer into the country's schools, and driven young minds will learn to critically consider concepts currently being discovered by present day

researchers, producing persons capable of collegiate learning and researching prior to their pursuit of an institutional education. The scientific community will prosper with the addition of intellectuals proficient in theoretical analysis, and the world is more likely to benefit from these people's passionate research in the future. Such an end product is unachievable if general research funding is lacking. On the other hand, sufficient funding and likewise ample amounts of research provides an environment suited for an education system based on past and present theory taught from the work of inspirational individuals, inevitably producing students inspired to become such individuals themselves.

Improvements in education result in a better-prepared workforce, more intuitive and insightful individuals, and ultimately an improved economy. The effects of generalized research are great, and impact many sectors of the population, but it is difficult to conclusively deduce every area of the economy that experiences the benefits of basic research. However, extensive analyses have been conducted on the effects of federally funded medical research, and the results of such analyses may be used to consider how basic research may improve the country's economic condition. For example, Brown University's Medical School's Division of Research found that the "return on investment" from funding medical research in the 1970s and 1980s was very high, and, by translating the value of life and health into dollar amounts, the increase in life expectancy totaled \$57 trillion (Peipert, 2002). If medical research, a form of applied research, has such a high return for human beings, then general research, with its ability to exploit unknown knowledge and open doors for human development and technological advancement, must have a much higher return and thus even greater benefits to mankind.

In another study by the Lawrence Berkeley National Laboratory in Berkeley, California, research into modern building design was found to indirectly improve the economy

by reducing respiratory and allergy sicknesses in building residents. By increasing a building's rate of air filtration, ventilation and air circulation, the spread of communicable respiratory illnesses (e.g. common cold, influenza, etc.) can be significantly reduced (Fisk, 2000).

Constructing buildings designed to reduce the spread of illness will result in better productivity of the work force and reduce health care costs, while also improving the lives of citizens and saving energy with more efficient buildings. If implemented, the general research category of building design has the potential to drastically affect the economy, improve living conditions, and, through more efficient designing, aid in conservation of energy.

The benefits of basic research not only provide a way of increasing the country's quality of education and economy, but can also impact society by increasing man's knowledge of the physical environment and providing opportunity for technological advancement. The efforts of past researchers have provided countless household appliances, communication devices, and products that are used daily by millions of people across the earth. Researchers Kathleen Danna and Daniel Nathans are paramount examples of this sort of contribution to society, and have become historic figures in the field of molecular biology, for their work not only aided in the success of the field, but most molecular techniques used today in DNA amplification and sequencing would not exist without their research in the early 1970s (Roberts, 2005). Previously, Hamilton Smith described and characterized a restriction enzyme—"endonuclease R"—that could cleave or cut a specific section of DNA (Mann & Smith, 1977). Though his discovery was monumental, it took intuitive researchers such as Nathans and Danna to see the potential of an enzyme with specificity, and apply it to the field of molecular biology (Danna & Nathans, 1971). Consequently, the findings of Smith, Hamilton, and Danna, have led to a world where gene mapping and cloning are a reality.

Another prime example of the unexpected benefits of general research is the neurological findings of the aforementioned avian biologist Fernando Nottebohm, who spent his time studying song acquisition and song learning in adult birds. Before his findings were published, it was common knowledge in the scientific community that neuron regeneration occurred only early in development, and not in the adult brain. Nottebohm found that there are several locations in the songbird brain where neurons are regenerated during adulthood, and his findings reformed modern neuroscience by questioning the currently accepted concept that the brain works solely through synapses between neurons (Eisenstein, 2004). These findings are also providing an answer to the most vital question in neuroscience: how can a damaged brain or spinal cord be repaired without further damage? The answer, found in Nottebohm's birdsong research, lies in the stem cells that produce new neurons in the brain and transport them elsewhere for replacement (Eisenstein, 2004). Nottebohm's intention was not to discover a mechanism for regeneration of the human spinal cord, but his research has opened doors that someday may allow neurologists to do just that and more. If scientists are allowed the freedom to explore their fields of interest, and are provided with the funds to do so, the end result is quite possibly revolutionary. Nonetheless, the revolution may never happen if the opportunity is not there, and, sometimes, the opportunity can only present itself when federal funding opens the door to limitless possibilities.

Money is the deciding factor in many situations, especially where the government is involved. Many times, though, competing interests must fight for the same funds and the more powerful voice will prevail, leading to a bias in distribution of funding. The unfortunate side to this situation is that in moments of economic hardship, general research seems to be the least favorable use of federal money, and may therefore have the least powerful voice, but is quite

possibly the most beneficial avenue in the long run. This point is difficult to argue when the end result of granting federal money to researchers is unknown until some life-changing conclusion emerges from their efforts. Therefore, the biggest motivator may be a comparison of correlations between research funding and education quality between several developed countries. There is no greater motivator than education quality, for if the future generations of this country are not capable of theorizing and critically evaluating their environment, such as their predecessors whose names appear in classroom texts, it raises a question of how successful humanity can be in the future. It may seem that life-changing discoveries and technological advancements are the sole reasons of research, but they are actually only benefits of theorizing and learning about the environment. The ultimate goal of research is creating, developing, and refining scientific theory. This goal is the reason that scientific education exists; theories are passed on between generations and modified through extensive research by passionate individuals who expand on previous theories. If research funds are lost, the education system will be compromised, and humanity's great accomplishments may be threatened by unwillingness to grant federal funds to researchers—the men and women who have given humanity a history.

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