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The Invention of New Science

Abstract

A definition of the current state of science and the vital role scientists have in the world are presented. Then, by looking at past and present trends, a prediction is given of some of the major themes that may be present in the future of scientific fields. A focus is put on the predictions of increasing collaboration, continuous scientific self-innovation, as well as the further involvement of interdisciplinary fields in the science. Some problems that are also present in today's scientific community are addressed and potential solutions are suggested. Our species will never run out of questions to ask, and science will continue to grow in importance as these questions are answered.

New Science Is...

Science provides hope for a better future. New technologies and discoveries are made every day that change the way we understand the universe. Our species will never run out of questions to ask, and science will help to provide answers about the unknown. Science cannot solve our problems, but it can provide us with the information necessary to make appropriate decisions. Some people may believe that discoveries like nerve agents, gunpowder, or the atomic bomb are to blame for the deaths of countless humans, but none of these inventions should be blamed. Our species' inanimate discoveries will always follow the laws of the universe, and it is up to humans to decide how these inventions are used. These discoveries are similar to a rock on the beach: depending on how humans choose to use the stone, it has the potential to be used for destructive purposes or could be used to improve society. Likewise, an airplane is no more deadly than it is a marvelous tool that represents our understanding of the world around us. We may use it to transport food to the hungry just as easily as we could drop bombs on our enemy. Humans are solely responsible for both the benefits and destruction that results from the application of our knowledge about the universe.

Science is a way to increase our understanding of the universe by using experiments and logic to arrive at an explanation that is both testable and yields repeatable results. Science is not an object or a belief. Instead, it is a process and a tool that allows us to learn and discover. The scientific method does not contain moral guidelines or an ethical code within itself. The scientific process is designed to be factual, logical, and unbiased. However, when the human element is introduced, this process becomes corrupted with emotions and biases. Humans must therefore analyze their beliefs to make decisions about how to apply knowledge gained from scientific discoveries. Ideally, these judgments would be made based on information obtained by scientific means. The contamination of the scientific process from personal biases and objectives is inevitable. However, if scientists are aware of how their beliefs may affect their research, the impact of these effects can be minimized.

Each human has different beliefs about the world, which is the origin of problems regarding scientific advancements. As long as humans continue to understand the world differently, conflicts will always be present. It is not a scientist's duty to decide how a discovery should be used. Instead, it should be society's decision and should look to the scientists for facts and guidance whenever necessary. Scientists have the responsibility to remain as unbiased as possible during every stage of the scientific process – from the data collection, to the analysis, and to the report to others. A scientist also has the duty to provide people with evidence and not to tell people how to think. Certain ethical challenges may be presented from time to time. For example, there are many ethical issues regarding cloning a human being, but there are possible benefits as well. A scientist should look to society as a whole on how to answer these controversial issues rather than making a decision based solely on his or her beliefs.

Our understanding of the world around us is always changing. What is understood to be true today may be disproved tomorrow. A scientific fact refers to a concept that is believed to be well studied and has always yielded the same result. These scientific facts do not declare with absolute certainty that they are true. Rather, there is considerable evidence from repeatable experiments that support the scientific fact, and it has yet to be contradicted.

...A Collaboration of Individuals

Our true potential as a species is accomplished only when we communicate effectively with each other. Communication for political and economic reasons are vital to our society, but collaboration in the sciences is just as important. As we continue our scientific pursuits in the 21st century, there are many scientific endeavors that are too expensive and/or complex to be studied by only a handful of people. Through collaboration, ambitious goals can be achieved that would have been nearly impossible otherwise.

One example of the importance of collaboration in the sciences was the Human Genome Project (HGP). The HGP was started in 1989 with the objective of sequencing the roughly 20,000 to 25,000 genes in human beings (Genome Science Program, 2011). Although the project was officially completed in 2003, more detailed studies are still being published today (Genome Science Program, 2011). There were two major forces that led to the completion of this project: public researchers funded by the government as well as private ventures. This mixture of public and private industries spurred competition and technological development. Celera Genomics, a private company led by the American researcher Craig Venter, used a technique called whole genome shotgun sequencing (Office of Science and Technology Policy, 2000). At a cost of $300 million, the Celera research was a fraction of the $3 billion publicly funded project and proceeded at a faster rate. Celera's use of the shotgun sequencing led to the modification of HGP's original clone-by-clone strategy, resulting in a rapid acceleration of the public researchers' efforts (Scherer, 2001).

Celera Genomics planned to patent a number of the genes; they would not allow the data to be freely redistributed, and they put restrictions on the use of their research for scientific means (BBC, 1999). UC Santa Cruz, a publicly funded research group, initially agreed to collaborate with Celera and share data, but Celera refused to put its research into the public database GenBank. Although Celera did not share its research with others, the group still incorporated public data from other groups into their own genome model. In March of 2000, President Clinton stated that the genome sequence could not be patented, and should be made freely available to all scientists (Office of the Press Secretary, 2000). Unfortunately, the biotechnology sector's stock plummeted after the President's announcement with a loss of $50 billion in market capitalization in two days (Office of Science and Technology Policy, 2000). Special issues of *Science* and *Nature* were published in February of 2001 containing a working draft of the genome sequence from the public HGP and Celera Genomics, respectively; with the announcement that the HGP was complete, another special human genome edition of *Science* and *Nature* were published in April of 2003.

If the private corporations had not been motivated to be involved in the sequence of the human genome, the HGP might have taken longer to complete at a higher cost. Also, the pressure to think of alternative methods to sequence genomes might not have been present. President Clinton's decision to restrict patenting of the human genome was controversial, but was an important decision that had to be made. The decision eliminated a considerable amount of the demand for the private industry to research the human genome, but it resulted in allowing scientists to have free, unlimited access to unpatented information about the human genome.

Most of the collaboration for the project occurred in government-sponsored research centers and universities from China, France, Germany, Japan, the United Kingdom, and the United States. The HGP would not have been possible without the collaboration from the scientists as well as the public. Another large international project, the International Linear Collider is planned to begin in 2012 and completed in the late 2010s. Collaboration on the international scale is becoming more common as collaborating over the internet becomes easier; scientists from America, Asia, and Europe meet regularly via videoconference as they plan the research for the International Linear Collider (ILC, 2007).

...Innovating Itself

One of science's great attributes is that it builds off of itself. Scientists look to previous research for data, conclusions, and new questions. As we answer questions previously posed, more questions are generated. Even if an idea is not supported by data, progress still results. A scientist should always share data disproving his or her hypothesis. Sharing negative results may help to prevent future scientists from following steps previously taken, and it can also increase the credibility of a correct hypothesis. When scientists discover their ideas are not supported by the data, more questions can be asked, continuing the scientific process. There are no dead ends in science, only progress.

New technologies sometimes allow new fields or ideas to be studied. Geophysics has been studied since as early as the fourth century BCE when the first compass was invented in China. Today, the field of geophysics is much different than it was over two millennia ago. Geophysics owes this change to the progress of related scientific fields as well as the introduction of new technologies; studying mantle heat flow in the fourth century BCE would have been incredibly difficult due to a lack of knowledge about Earth's interior plus an absence of technology necessary to measure mantle convection. As technologies were introduced in the 20th century that allowed physical components of Earth to be studied much easier, geophysics research began to be published in increasing amounts. This rise of popularity can been seen in a Ngram Query[1] (Fig. 1). The rise of many other scientific fields that are also dependent on technology, such as molecular

1 A Ngram Query uses software developed by Google that scans through published works across many different languages for key words or phrases. The software then determines the percentage of words that relate to the search term printed each year, providing a rough guideline of how popular the term is over time. (Access at: http://ngrams.googlelabs.com)

biology (Fig. 2) or paleoclimatology (Fig. 3), share the same type of rise in popularity. As science creates new technologies, these technologies can lead to new scientific research.

Our knowledge of the world is growing at an increasing rate. It would be safe to assume that more innovation will occur in this century than the last. Just a little over a century ago, the Wright Brothers flew their first successful powered flight. Less than sixty-six years later, men walked on the moon and returned home safely. Twenty-nine years after the moon landing, the first component of the International Space Station was launched into space. Computers and the internet have drastically changed the world in less than a single human lifetime. There is much, much more left to be discovered. Some of these discoveries can be predicted because we experience negative effects from the absence of the solution, such as a cure for cancer. It is harder to predict other inventions if they will solve a problem that has yet to be clearly identified. For example, the idea of a computer in the 18th century would been unlikely because it addressed problems that were unknown at the time. Who knows what the future will bring due to scientific innovation?

…Interdisciplinary

Modern science has always been interdisciplinary. In general, science attempts to discover the physical truths about the inanimate components in the universe while art is concerned with emotional truths regarding the animate world. Both of these approaches to uncovering truths demand creativity. From Michelangelo to Van Gogh, from Newton to Mandelbrot, each person was incredibly creative. This creativity provided them with an outlook on the world that nobody before them had experienced. Ideally, the best scientist would have tremendous knowledge of every area of study, also providing a different perspective when solving problems. Today, with so many different fields that are constantly evolving, it is impossible to know all the information in even one field, let alone all of them. Instead, scientists should strive to know as much as possible from a wide variety of disciplines. Einstein said in 1923, “The greatest scientists are always artists as well." A scientist that has a well-rounded education will have different perspectives and ideas than a scientist that focuses only in his or her field. Frequency-hopping spread spectrum, which is a technology commonly used today to encrypt cell phones, was invented by composer George Antheil and actress Hedy Lamarr. Samuel Morse, the inventor of the telegraph, and Robert Fulton, the inventor of the steamboat, were both very accomplished artists before they made their famous discoveries. Dr. Bob Root-Bernstein, a physiologist and MacArthur Fellow, wrote:

> [A]lmost all Nobel laureates in the sciences are actively engaged in arts as adults. They are twenty-five times as likely as average scientist to sing, dance, or act; seventeen times as likely to be an artist; twelve times more likely to write poetry and literature; eight times more likely to do woodworking or some other craft; four times as likely to be a musician; and twice as likely to be a photographer.

Those that have a wide range of proficiencies will have be able to approach problems from different perspectives, and different perspectives can lead to progress and innovation.

As we make new discoveries, new scientific fields are occasionally created. These new fields are not always unique, “never heard of before” disciplines; sometimes, different branches of science can be combined together to create a new area of study. This is true for the field of geophysics, which (obviously) owes its origins to the fields of geology and physics. Although some of the terminology, nomenclature, and focus of geophysics is different from geology and physics, the fields have many similarities. In fact, most scientific fields overlap considerably with other fields. Not only are scientific fields connected with each other, but the sciences are connected with the arts as well. Although disciplines often overlap, each discipline has key differences and are unique. These differences create the richness and diversity of human civilization.

What I hope will be true in the future

Until the 1920s, scientific papers were often credited with a single author. Today, it is extremely rare to find a single scientist that knows enough information about a topic to publish a paper without help from others. Today, a typical issue of *Nature* has roughly the same number of articles compared to an issue printed in 1950, but there are about four times as many authors being credited now; some scientific papers list more than 100 contributors. It has become so difficult to determine the actual contributions of each individual that the crediting system must evolve. There should be a more specific crediting policy that lists each scientist's role in the research rather than a list showing the relative importance of each individual's contributions (Greene, 2007).

Ideally, scientific discoveries should be shared freely with everyone. The economic status of an individual should never prevent him or her from access to the most current knowledge. Libraries are excellent resources, but are often underused for a number of reasons. Depending on where someone lives, he or she might not have easy access to a library. Also, poorer communities might not be able to provide the same resources compared with libraries and schools located in more wealthy regions. The typical library also has limited resources such as money and space; it is not possible to provide every resource at every library. Many libraries have subscribed to online databases that contain countless articles from a wide range of years. However, these databases are expensive to subscribe to, and there are many different databases for different fields of study. Even though these databases are accessed electronically via the internet, access may be limited to computers at the library (or in the case of schools, the computer may be required to be on the local network).

A central database that contains all types of published works and that can be freely accessed on the internet would solve some of these issues presented. Anyone could search for information from their residence, school, or workplace. Current research on any subject would be at the fingertips of any scientist anywhere in the world. According to the International Telecommunications Union (ITU), 71.6% of people living in developed countries (30.1% in the entire world) had internet access in 2010, and the number of people with internet access continues to grow each year (ITU). Also, the United Nations declared internet access was a human right at the World Summit on the Informational Society in 2003. Because of the growing popularity of the internet worldwide, access to a free, central database of research would be incredibly useful to scientists and other people worldwide.

Another issue that may prevent scientific advancement is funding. The traditional, common approach to fund research is to apply for funding, receive funding, then conduct research. There are a couple of problems with this system. If a group is funded to do research, the success of the research is unknown and the money might not lead to any progress or development. Also, only the individuals that receive funding will be working on a solution. Awarding “prize money” for the successful completion of a project has been growing in popularity over the past few decades. These include the Loebner Prize in the field of artificial intelligence, the Millennium Prize in the field of mathematics, and the Google Lunar X Prize in the field of privately-funded space exploration.

There are some important benefits from this type of funding. The research is not limited to a certain group of people; anyone can participate and is eligible for the reward. This allows all types of people with different backgrounds and expertise to use their ideas to achieve a common goal, which spurs innovation. Also, the funding will never be wasted. The money is only awarded upon the successful completion of the project. However, there are drawbacks to providing “prize money” for research. Depending on the type of project, initial funding may be necessary. Therefore, this system is only applicable for low-cost research or to groups that have access to money before the competition starts. Without an agency funding the research, the researchers are the ones that are the ones that must gamble due to the possibility that they are unsuccessful in their endeavors. Also, awarding prize money is limited mainly to projects that require large levels of innovation and might not be suitable for projects where procedures are already well defined. Nevertheless, there are many situations where offering prize money could yield incredible results.

Conclusion

As we continue to research and innovate in the 21^{st} century, we may see a larger amount of collaboration, continued innovation, and more interdisciplinary research. Scientists must continue to conduct impartial research and present all findings, especially if the results contradict the original hypothesis. We must continue to question everything, even if an answer has been determined to be valid. New technologies that are introduced may make current research easier as well as pave the way for new branches of science to be studied. This century will be full of incredible research and innovation, and it will be no doubt be a thrilling adventure.

Figures

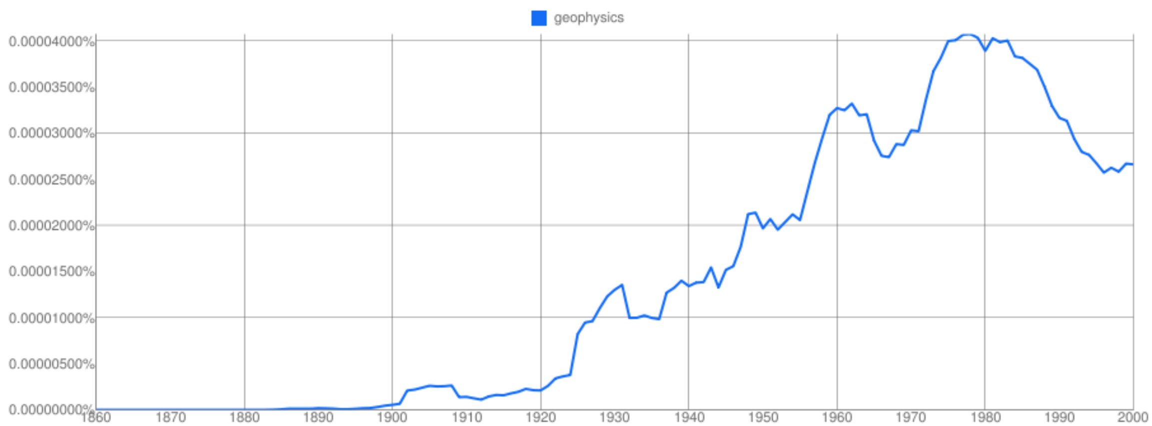

Fig. 1. Ngram Query of 'geophysics' from 1860 to 2000 (http://ngrams.googlelabs.com).

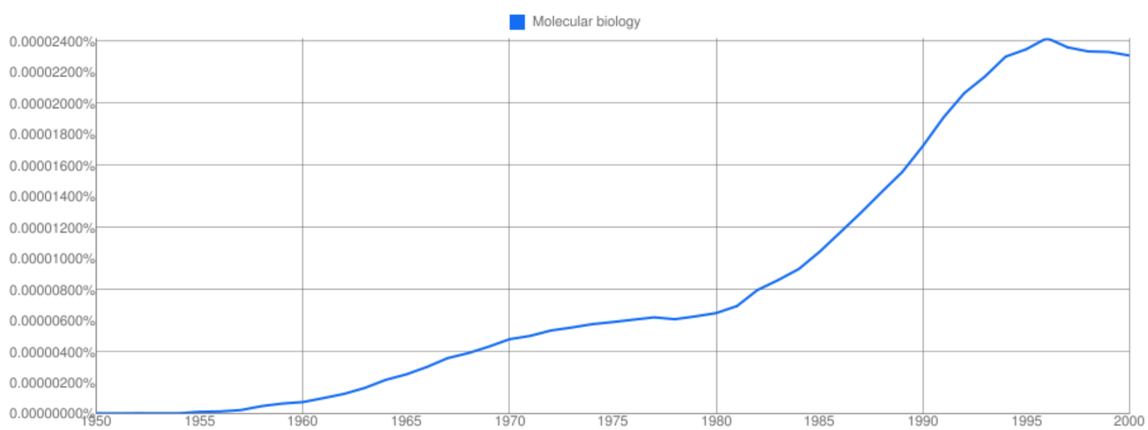

Fig. 2. Ngram Query of 'molecular biology' from 1950 to 2000 (http://ngrams.googlelabs.com).

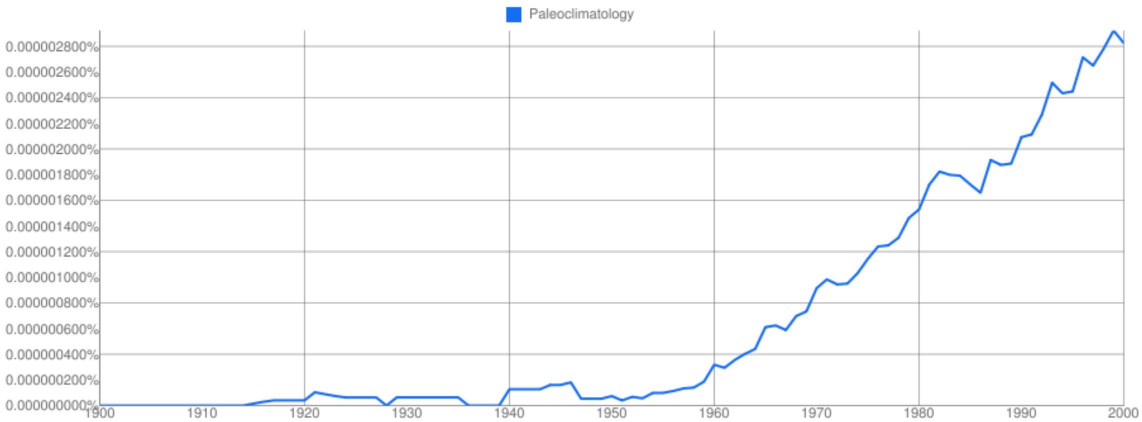

Fig. 3. Ngram query of 'paleoclimatology' from 1900 to 2000 (http://ngrams.googlelabs.com).

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