Do We Need Fundamental Research?

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Today, we find modern technologies everywhere in our daily life: computers, smart phones, navigation systems, wearables, high-tech medicine. Usually, they did not come by chance. These technologies are a result of fundamental research and breakthroughs and were developed by scientists, engineers and clever inventors.

What is Fundamental Research and Its Role?

By definition, fundamental research is not purposeful. A modern society invests several billion euros per year into research and development (R&D). This is not a luxury issue. We have to invest a significant amount of a country's gross domestic product (GDP) to develop new methods and technologies. These are essential for our economy, our prosperity and they are vital to face the challenges of a modern society. And there are quite a lot of challenges at the beginning of the 21st century: climate change, exhausting energy resources, terrorism, an over-aging society and, most recently, refugees coming to industrial countries for various reasons like war, terrorism or poverty. One example: Our knowledge about anthropogenic climate change is a result of modern science. About 800 scientists worked on the recent 5th assessment report of the Intergovernmental Panel on Climate Change (IPCC).[1] This report was only achieved by an international interdisciplinary collaboration of scientists who were financed by many countries with several billion euros over decades. The IPCC found evidence that mankind is responsible for global warming, mainly driven by the emission of carbon dioxide from our industries and traffic. This effect is seriously evolving as can be seen, e.g., from the following fact: Consider the (on average) ten hottest years since data archiving which started in 1880. Nine of these ten hottest years were after year 2000! Our modern society urgently has to find a solution for this climate change problem. The IPCC researchers are capable of forecasting our future using modern climate models. If we go on like we used to do, we will run into a significant mean temperature increase of about three degrees until year 2100 or even eight degrees in the worst-case scenario. Extreme weather events (violent storms, droughts) will appear more frequently. Coasts will be flooded due to increased sea levels. To prevent that from happening, we need new efficient CO_2-free technologies – now.

A Sidewalk through History

How did we end up like this? It is interesting to have a closer look on the evolution in the field of energy resources. History tells us how mankind discovered new resources, e.g. steam engines or electricity, and sooner or later was able to make use of them. New technologies come along with scientific discoveries. From our present perspective it is funny to remember that about 100 years ago there was a poor understanding of particle physics, for example. At that time, only two particles were known: the proton and the electron. Meanwhile, we now know more than 20 elementary particles (6 quarks, 6 leptons, the photon, 6 gluons, W^+, W^-, Z^0, and the Higgs particle)! And it turned out that the proton is not an elementary particle but consists of quarks. Furthermore, the notion "radioactivity" was coined in 1898 by Marie and Pierre Curie. The couple dedicated their life to fundamental research and they paid a high price because they did experiments with unknown and very dangerous chemical elements like Radium or Polonium. Thanks to their devotion for the unknown, we now know so much more about the nature of elementary particles and matter. This knowledge is vital to develop new technical devices and new experimental methods. Radioactivity was also used by Ernest Rutherford to investigate matter. He did scattering experiments with energetic particles (alpha particles) on gold foils and formulated a powerful atomic model. Later on, particle physicists built particle accelerators. They took electric and magnetic fields to accelerate and control electrically charged particles. By smashing them together they found new particles. This strategy is the same for the most powerful particle accelerator today, the Large Hadron Collider (LHC) at CERN. In summer 2012, it was proven that our knowledge of the microscopic world is still incomplete. The fundamental Higgs boson, a spin-0 particle, was found. The "Higgs" is responsible for the rest mass of all other fundamental particles. It seems that there is still a strong motivation to invest into fundamental research – not only in a discipline like particle physics.

A Modern Society Benefitting From Fundamental Research

The Higgs boson might be an example of something, which does not immediately affect applied sciences. It appears

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that in the next 20 or 30 years or so there will be no useful device, which is built on Higgs physics. Nevertheless this kind of fundamental research is extremely important because it is a puzzle piece in our understanding of the world. In a sense, Higgs physics is a cultural asset like classical music or contemporary literature.

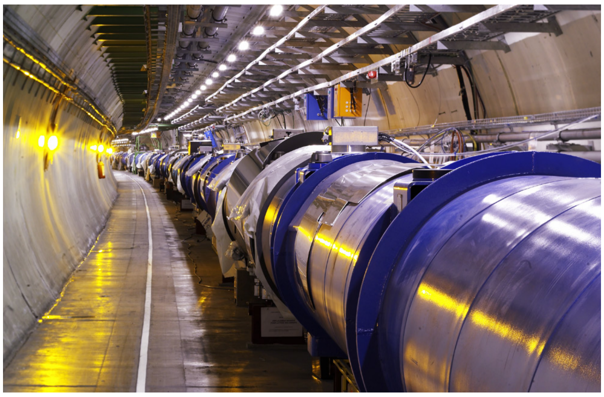

Figure 1: The Large Hadron Collider (LHC) at CERN is a multi-billion euros facility for several thousand scientists and engineers doing groundbreaking fundamental research. (Image credit: CERN)

Of course, you never know what can be the result of a long lasting scientific endeavor. Take the laser physics as another example. The acronym "laser" stands for light amplification by stimulated emission of radiation. The foundations of laser physics date back to 1917 when Albert Einstein contributed to the quantum nature of radiation. He found probability coefficients (nowadays called Einstein coefficients) which are important to our understanding of stimulated emission, a phenomenon which is a precondition to build a laser. Today, when we look around, we find lasers in everyday items like a DVD player or a laser pointer. Lasers are also important to manipulate matter on a microscopic scale. Here we see that the timescales for bringing fundamental research into daily life could be long, something like 100 years. The bottom-line is clear for everyone to see that we are benefitting from these investments into fundamental research – sooner or later. Accidental discoveries also play a crucial role in this context. Two examples: The cosmic microwave background (CMB) radiation was discovered in 1964 while radio astronomers were investigating the Milky Way. In 1928, the effect of Penicillin was discovered by chance as well in a hospital in London. Without fundamental research both would not have been possible. Both were breakthroughs: The CMB tells us about the birth of our universe in a hot "Big Bang"; Penicillin helps us to cure bacterial infections. There are also important secondary effects while doing fundamental research. Another benefit can be seen, e.g., at CERN: There are large international collaborations with several thousands of individuals cooperating peacefully for their research goal – no matter which origin, race or religion they may have.

A Modern Society Benefitting from Fundamental Research

Now that sufficient motivation has been established to invest into fundamental research, the remaining crucial questions are: How much should a modern country invest? What is the fraction of Germany's gross domestic product which is fed into R&D? And from a global perspective: Which nation invests most? The R&D investments of Germany amounted to 80.2 billion euros in 2013 which equals 2.85 % of Germany's GDP. The largest contribution came from the German economy (53.6 billion euros) because branches like automobile, computer, telecommunication, electronical, chemical and pharmaceutical industries invest quite a lot into R&D and significantly increased their investments in 2013. Compared to other European countries there were only three countries which invested more into R&D in 2012, namely Finland (3.55 % of GDP), Sweden (3.41 %) and Denmark (2.99 %).[2] The fraction in France amounted to 2.26 % and 1.77 % in the UK in 2012. The European average was 2.06 % in that year. In 2011 there were non-European countries which invested significantly more into R&D, e.g. Israel (4.38 %), South Korea (4.03 %) and Japan (3.39 %). The fraction for R&D in the U.S.A. was 2.77 % in 2011 – i.e. at a comparable level to Germany. The 3-percent-goal for Germany was achieved in 2012 with 2.98 %.[3] Let us compare the absolute numbers of R&D investments, e.g., national defense budgets. The German Government invests something like 30 billion euros here. Multiplying this by a factor of 20 we approximately get the US-American budget (nearly 600 billion USD).

A Pleading for Fundamental Research

For a modern society it is absolutely crucial to continuously invest into R&D and fundamental research. It seems reasonable to fund R&D with 3 % of a nation's GDP. This has to be done over a variety of disciplines and from the industries as well as from the governments. The R&D achievements in the last 100 years clearly show that mankind enormously profits from these investments and that the findings, sooner or later, influence and facilitate our daily life. The time scales for these changes are rather long, decades or even one century. However, the impact of new technologies can be very high, see e.g. computers, the internet, or smartphones. Funding agencies should not have the narrow perspective to exclusively invest into industrial R&D, applied sciences, or industrial projects with a dedicated application-driven goal. History tells us that also the funds for fundamental research, which is not purposeful by definition has its return on investment and, of course, an understanding of our world in general represents a cultural asset.

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