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What's the point of theoretical physics?

Pure theoretical studies in physics can sometimes lead to amazing changes of our society.

Looking back in the history of physics there are several examples of purely theoretical investigations that resulted in extremely successful industrial applications.

About one hundred years ago Quantum Mechanics was a purely theoretical topic, only developed to understand certain properties of atoms. The founding fathers like Bohr, Dirac, Heisenberg, Pauli, Schroedinger and many others had no applications at all in mind. They were simply driven by the quest: what is our world made of? Due to the fundamental changes about our concept of observing nature - Quantum mechanics states that you can not observe a system without changing it fundamentally by your observation - initial effects to society were of philosophical and not of practical nature. Today Quantum Mechanics is the basics of all semi-conductors. Thus all your computer equipment, mobile phones,.. rely on it. Einstein's interpretation of the photo effect enabled us to understand emission, absorption and stimulated emission of photons from atoms. This is the starting point to develop lasers, which are also present in every day live. Einstein's general theory of relativity, which celebrated last year the 100th anniversary, started out as a pure quest to understand gravity, the dominating force of the macrocosm: can we really predict the planetary motions in detail, in particular the deviation of mercury's orbit from Newton's prediction (perihelion precession)? Can we understand the mechanics of the whole Universe? Einstein found a completely new way of describing the force of gravity simply by a curvature of space-time. Today the most common application of the general theory of relativity is the exact determination of your own location via GPS. Einstein clearly could not have imagined this application 100 years ago. A more recent example is invention of the www at CERN by Tim Berner-Lee. Berner-Lee had no Amazon, Facebook,… in mind when he was creating a system for sharing scientific

information among different universities and institutes. So many of the pillars on which our society in the year 2016 rests, were created by pure theoretical investigations.

Comparing these facts with the original motivation for doing fundamental science is quite astonishing. In contrast to applied science, where you already have a certain result in mind, you simply want to improve the understanding of nature by doing fundamental research. May be it all started by looking up to the night-sky in ancient times. Humans wanted to understand the world and the universe they are living in, they spent some time watching nature and created first theories about nature - many of them involving several gods. Compared to these ancient times, we made huge progress in understanding stars, galaxies, the whole universe, but also on the other extreme of length scales, in the microcosm. We know now that matter is built of atoms, which are built of nucleons and electron - the former being built of quarks. However, this huge progress in understanding nature, went along with newly arising questions, like finding evidence for huge amounts of dark matter in the universes, which nobody ever has detected directly. It somehow seems that every new level of understanding we achieved, came in pair with new, more fundamental questions. Of course, we do not want to stop thinking at a certain level. It is not enough to know what we know now! We want to continue looking behind newly arising curtains. In that respect, I consider fundamental physics as a basic part of human culture and like other parts of culture (theatre, museums,..) .

In public discussions many times the high costs like several billions for the large hadron Collider (LHC) at CERN or roughly half a billion for LIGO (and experiment to detect gravitational waves that were also predicted by the general theory of relativity of Einstein) are in the focus. But these numbers should not be compared to ones individual salary - except you are Bill Gates - but to overall budgets of countries. For the US military budget in 2014 (581 billion $ according to Wikipedia) one could build more than 140 Large Hadron Colliders (4 billion $ accelerator cost according to Wikipedia) per year. Having also the above spin-offs of fundamental physics in mind, the price for LHC, LIGO a.s.o. seems to become smaller and smaller. But there are also direct financial benefits of doing fundamental research. Most of the student and post-docs working e.g. at CERN, will not stay in academia, but move into industry. During their time in fundamental physics, they were educated at the highest existing

technical level and they bring their expertise directly into industry. This is like educating car mechanics in formula one racing teams.

Even if scientists today are pushed hard to bring in external funding to universities, my my motivation for doing science is still to improve our understanding of nature, without any having any lucrative spin-offs in mind. Related to such consideration there is a nice anecdote from Robert R. Wilson, the founder of the big american particle physics institute, Fermilab. While defending the Fermilab budget in front of a congress committee, he was asked, whether all these activities will help to defend the country. “It has nothing to do directly with defending our country except to help make it worth defending.”, he replied. Being in the lucky situation that experiments like LHC and LIGO are currently financed, we can curiously wait for new insights in the building plan of nature they will bring us in the near future - and also to what unforeseen spin-offs a higgs-boson or a gravitational wave might lead in the long term future.