'Progress in Science is impeded by great ideas that become accepted wisdom.' Discuss.

In the 1950s, progress was thought to be “development by accumulation” (Kuhn, 1962). However, in his analysis of ‘Science’, Kuhn put forth a more radical view, the fact that progress is a revolutionary process which occurs when new ideas are adopted and old ideas are abandoned. These ideas are sometimes widely accepted despite not being rigorously proven, as the examples below show. While progress could potentially be impeded due to this, the impediment caused is rarely serious enough to cause significant damage. Moreover, my argument is that these assumptions are necessary for progress, and there are examples throughout scientific history which show that taking assumptions to be true have led to scientific breakthroughs. For the purposes of this essay, I will be discussing Science as a collective body made up of other fields of study. I will be considering 4 case studies, one in each main field of Science to construct my argument – Chemistry, Physics, Biology and Computer Science. I will also be including other examples, as necessary, to warrant my argument.

Progress is defined as “a forward or onward movement” (Oxford English Dictionary, 1989). However, there is no requirement that advancements happen continuously. It could be argued that sometimes taking a step back will help move forward more effectively. In the end, scientists always find a way to get to the desired result; as Kuhn says, scientists define problems in a precise enough way that they can always be solved (Horgan, 1996). In addition, if a particular theory does not yield results, scientists can learn from their failures and gain new information leading to alternative solutions. Moreover, if one scientist's ideas and methods have been proven wrong, another could take his place and come up with a different method to solve the same problem. Therefore, no work is 'wasted' and progress still continues, albeit at a slower rate than possible.

The story behind the creation of the periodic table suggests that progress still continues despite assumptions being made. Dmitri Mendeleev was a Russian scientist from an orthodox Christian family. He gave up religion at a young age to pursue Science, at a time when clashes between religion and Science were frequent (Gordin, 2004). His key contribution was in the field of Chemistry, when in March 1869 he gave a presentation to the Russian Chemistry Society listing all the known elements of his time and predicting future elements in an organised table. The new periodic table became widely accepted, despite Mendeleev providing no experimental proof for its validity. It took 10 years of further research to find the missing elements - Gallium and Germanium - and confirm their properties before Mendeleev's table gained credibility (Emsley, 2001).

Assumptions made by scientists are often used in further research, especially for the use of proofs (Horsten, 2006). This could cause a problem in the future, if the original assumption is proven wrong for example. Any consequent proofs based on the wrong assumption are then invalidated and will need to be re-written from scratch. However, the original research carried out is still useful and can help in forming a new proof. This could even lead to an increase in rate of progress, as another motive is created for scientists to continue research and solve a problem. Advancements in Physics, and specially the development of the (still incomplete) Standard Model of Particles indicate this idea. For over 2000 years, the belief that atoms were the fundamental particles governed research in particle Physics. In fact, the word "atom" comes from the Greek word 'atomos' meaning 'indivisible'. When the idea of the atom was first conceived, it was believed to be the smallest particle to ever exist. With no proof, and indeed, no way to prove this in ancient Greece, the scientists of the time worked on the assumption that this was true. Democritus' theory from 460BC was widely accepted until the early 20th Century (Ponomarev, 1993). It took Ernest Rutherford and the discovery of radioactivity to finally find evidence for sub-atomic particles in 1910 (Nobel Prize, 2013). Even nowadays, the search for particles at CERN is dictated by theories established in the previous century. Most famously, and in the public eye, is the discovery of the Higg's Boson. This particle, dubbed 'the God Particle' is very important to Particle Physics, as it reveals the fundamental property of matter. It was famously predicted by Professor Peter Higgs of Scotland in 1964 almost 50 years before CERN officially announced the discovery of the elusive particle. In the intervening years, progress continued, and at a very rapid pace. Today, there are still predictions incorporated into the Standard Model for which there is no experimental backing. However, their potential existence is enough to fuel the search for the particles, at CERN (University of Edinburgh, 2013) and other laboratories worldwide. The predictions by themselves give researchers round the world a motive to continue research.

In contrast to the previous arguments, there are some cases that indicate that progress is impeded by ideas not being accepted in the first place. One such event is the "Ox-Phos wars", a period of more than 15 years when Peter Mitchell a (slightly eccentric) British biochemist put forth a controversial idea that was not accepted by the scientific community at large. By the 1950s, it was proven that ATP was created from glucose in food. However, the popular belief was the existence of an intermediary particle that helped change the glucose to ATP. In contrast, Mitchell, in 1961, claimed that the intermediary stage was not due to a particle, but the existence of a proton gradient - a proton motive force. Working similar to a dam, protons were pumped outside the mitochondria, across the membranes, and in doing so, helped power the enzymes in the membrane. The enzyme – ATP Synthase – in turn used this energy to produce ATP (Lane, 2010). It took 20 years, and Mitchell to win the Nobel Prize in 1978 before his idea gained credibility. It then took a further 25 years for experimental proof to be found, when the process of ATP synthesis was isolated from the cell and recreated under laboratory conditions (ATP Synthase, 2008). If Mitchell's idea had been accepted when it was first postulated, the progress could have been much quicker. Although the desired result was eventually achieved, it could have been reached much earlier. This case study suggests that accepting ideas is not only useful, but essential for progress to occur at optimal rate.

Another case study which indicates the importance of assumptions is the Church-Turing hypothesis, in the field of Computer Science. Alonzo Church, an American mathematician and Alan Turing, his British counterpart, came up with the theory in the 1930s. This was before Turing achieved fame for leading the code-breaking efforts during World War 2 at Bletchley Park. Despite being most famous for that feat, his works in Computing more generally have led him to be widely recognised as the "father of modern Computing" (Homer, 2001). The Church-Turing states that a problem is computable only if it can be solved by a Turing machine (a theoretical machine that Turing came up with). This thesis is widely accepted in the Mathematics community, however, even after more than 80 years, there has been no formal, rigorous proof that outlines it to be true. Many other proofs, published since this thesis, mention the Church-Turing Thesis by name, and assume it to be true (Horsten, 2006). If this could not be done, a proof would only be valid if a Turing machine was created; an impossible task, as it is a purely theoretical machine with infinite memory and cannot be replicated in practise.

Considering an extensive point of view, imagine an alternate universe where human progress can only occur once each advancement is validated and there are no assumptions involved in the process. A time line of progress would look very different from our world today. However, the question is, would progress have simply slowed down or halted completely in such a universe? If the time line was extended 2000 years in the future, would humans in that alternate universe have achieved the same as we have by 4013? When looking at progress in Science, it is also important to consider the limitations of it. One such limitation already exists, in measuring the position and momentum of an electron. The Heisenberg Uncertainty Principle states that either one or the other can be accurately known, but not both simultaneously. This limitation is not due to the accuracy of instruments or human ability. It is the nature of electrons, as wave-particles which provide this uncertainty. (Nave, 2013) This suggests that it cannot be viewed as an impediment to progress, but a limitation of it.

A famous quote from E.T Bell, a Scottish-American mathematician and author of 'Men of

Mathematics' (1937) reads “Euclid taught me that without assumptions, there is no proof. Therefore, in any argument, examine the assumptions.” (Eves, 1988) Based on my research into this topic, I believe that while great ideas are accepted without evidence, the impediments they cause are outweighed by their necessity. These assumptions simplify a problem and increase the rate at which progress is achieved. While some of these assumptions lead to mistaken beliefs, these mistakes can also lead to solutions to these or alternative problems. The key danger with assumptions is the fear of failure. But Science is a subject where failure is not inherently 'bad' as any new information learned can be applied to find an alternative solution. Each person who works on a problem contributes a little to the big picture. While making assumptions has advantages and flaws, the evidence shows that the advantages outnumber and outweigh the problems caused. By limiting progress to ideas which make no assumptions, the advancement of not just fields within Science, but of humans, as a race would be limited. Imagine, for example, a world where technological advance can only occur without making assumptions. Would man have been to outer space? Would he have landed on the moon? Would he have sent a robot to another planet? Progress in any field of Science requires assumptions to occur. However, assumptions by themselves are also not sufficient. There have been some instances in history where not just assumptions but mistakes have helped advance science. As E.T. Bell said, “The mistakes and unresolved difficulties of the past in Mathematics have always been the opportunities of its future.” (IZquotes, 2013) Despite not strictly being a science, Mathematics has a close link to the sciences, and this quote is as valid for sciences as it is for Mathematics. Returning to the story of the periodic table, one of Mendeleev's original predictions – about the relative atomic masses of Tellurium and Iodine – was proven wrong with experimental data. The false predictions fuelled research into elements and their properties, leading to faster progress than would have occurred. Another – possibly more famous – mistake is the discovery of penicillin. Had Fleming not made the mistake or acted on his unfounded curiosity of the infamous ‘unattended’ petri dish (Brown, 2004), it is possible that the pharmaceutical industry would not be as advanced as it is today.

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