How does sciences improve its theories? It is easy to imagine it works much like biological evolution works (at the very least how many scientists currently believe biological evolution works). Extremely basic theories emerge from the primordial ooze of science. Further experiments and lead complex (accurate). Theories which do not stand up to scientific rigor will become extinct. This supports the idea that over time, our theories become better. It also seems to promote the idea that human bias is somehow kept away from science and that science is inevitably inching towards the truth. This is an evolutionary model of scientific discovery. Kuhn would most likely say this could not be farther from the truth. Instead, as described in his paper *The Function of Dogma in Scientific Research*; he argues that science has a much more dogmatic approach, possibly more similar to religious beliefs then many would admit. It is a common cliche that the strength of science is its malleability and willingness to change in face of new evidence. Kuhn points out that in many cases, this does not seem to be the case. "[a scientist] seems to know before [their] project is even well under way, all but the most intimate detail of the result" (Kuhn, 1963, p.348). Faced with contradictory evidence at least anecdotally, it seems much more likely they would "struggle with his apparatus and with his equations until, if at all possible, they yield the results which conform to the sort of pattern which he has foreseen from the start"(Kuhn, 1963, p.348). Issues with the experiment's design, instruments used or some human error will be blamed long before believing for example that Earth's gravitational constant is not 9.80 meters per seconds squared. This is because scientists tend to have a dogmatic scientific view that resists

change to overarching high-level theories. Their experiments are usually designed to gather more evidence to validate current theories. They have no interest in proving the established theories wrong. They only wish to make them more rigorous. I believe this can be summarized simply as what a scientist learned to be fact as a science student they are extremely unlike to change their minds on in their lifetime. New scientific theories, will generally fit inside the theories student learned as facts.

Kuhn refers to paradigm-based science, where the paradigm is loosely defined as the framework that a type of science is executed within. It includes the terminology, ideas, tools to be used, the important types of observations, are and what they mean. Scientists solve puzzles and the paradigm sets the rules to the puzzle. Science is based on the sharing of knowledge, so it is important for all to use the same paradigm to ensure results are compatible and form a single cohesive web of knowledge. Progress would not be possible if each scientist's results used their own paradigm. Kuhn details the early electricity scientific work when there were many scientists working in the same field but not sharing a paradigm. He concludes, "the immediate results of their activity was something less than science"(Kuhn, 1963, p.356). Without the structure of a paradigm, the scientific field can not progress. Normal science occurs when all the scientists in a field share a paradigm and make progress within the paradigm, not trying to change or improve the paradigm itself. It is important to note that often there are many possible available paradigms. It is not necessarily the case that the best one is used more accurately as they are non-comparable as they are based on different rules. It is simply necessary for a single paradigm to be used for normal science to occur. When a single

compressive paradigm is not used, Kuhn would likely say that something less then science is occurring even if the individuals are conducting science-like activities. His historical prospective points out that when a new scientific field emerges, lots of work is done by individuals and although individuals might make progress; it impossible for the field to move forward with scientists using different terminology, tools and conclusions on their observations. It is not normal science and it lacks the ability of scientific progress.

Karl Popper in his paper *Science: Conjectures and Refutations* addresses the same questions of the nature of day to day inquiries of scientists and the characteristics of proper scientific method; but comes to very different conclusions. Using his argument one would most likely come to the conclusion that the paradigm-less science that Kuhn would reject as normal science he would have no issue with accepting it as proper science as long as it was conducted with the appropriate empirical scientific method. He tries to understand the criteria a theory needs to be truly scientific. It is not hard to find examples of science coming to a wrong conclusion, such as the earth was flat. It is also not hard to image they could come up with a correct theory just by guessing and not using any evidence. This cannot be true science by virtue of the simple definition of science. Clearly evaluation criteria must be used other then correctness. When a scientist attempts scientific experiments “the impressive thing… is the risk involved”(Popper, 1965, p. 36). Before the scientific experiment is performed the scientist can predict the outcome using the theory to be tested. Kuhn made the same observation that scientific experiment will

have results predicted before hand. Popper believes this is very important because getting different results could mean, “the theory is simply refuted” (Pooper, 1965, p.36). Wrong results tell us the theory is wrong and a new one is needed. Kuhn’s paradigm model would refute this and suggest this would not be enough for the scientist to refute their theory (paradigm being used), instead the experiment would be repeated and altered in hopes that the expected results are obtained. Perhaps Kuhn would say Popper is wrong and there is no risk because unexpected wrong results are not enough to shake dogmatic views. Popper compares the risk he observes in scientific experiments with what he considers the pseudo-sciences, where results are used to confirm and explain the theory regardless on what the results are. The pseudo-scientist will always use the results to confirm their theory instead of refuting it. Popper might say that viewing sciences as dogma makes it unscientific. Falsification is a major corner stone of Poppers views of normal science. Performing an experiment and having the expected results occur does not prove the theory used for prediction is true. There are an infinite number of other theories that could predict the same results. Having the wrong results, on the other hand, truly does prove that the theory is wrong. Popper believes that for a theory to be scientific, it most be falsifiable. Normal science involves coming up with theories and attempting to falsify them.

The major difference: Popper believes that the scientific method identifies a problem to be solved, come up with possible theories, and performs experiments to falsify the potential theories. This sees scientists coming up with bold new ideas that best

fit a problem and doing there best to try and falsify them. This supports the idea that science is always changing and ever searching for the best model. Kuhn would say this is an unrealistic ideal to hold scientists to and his historical view shows that scientists do not spend their time trying to falsify theories, instead, they only work within a paradigm to strengthen it and will strongly resist change to the paradigm. On the question of day-to-day scientific inquiry, Kuhn seems to have successfully identified the meta strategy scientists use to promote a uniformed collective progress of science by working within a paradigm and producing more proof of the paradigm's correctness. Popper's view was more of a thought experiment in identifying the properties of a good scientific theory. This key property is that it can be falsified. It then follows that if it is falsified, then it should no longer be used. I believe Paradigms to some degree still to adhere to the falsification principles of Popper. They are used by the scientist are falsifiable. If they have inadequate predictive ability they will be refuted and replaced . If the scientific community is using them, they have not been adequately falsified. Popper potentially overestimated the rate of falsification of theories. One failed experiment not enough evidence, mistakes are often made. Scientists are only human, after all.

It might first appear that these are extremely mutually exclusive contradictory ideas. The debate seems to boil down to whether or not scientists are dogmatic. I would like to believe this is not the case and it is not strictly necessary to take only one side of the normal science debate. Popper was trying to answer the question in an ideal theoretical sense of necessary properties of good scientific theories. Kuhn, on the other

hand, was trying to determine what actually happens in practice with these theories.The use of scientific paradigms, I believe, is not strictly necessary for science to take place but rather a by-product created by the necessity for scientists to effectively communicate.

In historical and current times I think its clear that Kuhn's description of normal sciences is a more accurate description of scientists' day to day activities. With historical evidence like the early research on electricity, it seems clear that scientists need to work with an accepted paradigm to connect their work. Popper's description of normal science, though perhaps not practically feasible to progress the global scientific knowledge base because of the limitations of human communication of the scientific observations, it is still undeniably science. Kuhn goes on to describe that at a paradigm's unsalvageable failure, in other words when it has been falsified, a scientific revolution takes place and a new paradigm must be selected. This seems to be in line with Popper's description of falsification and coming up with bold new ideas. If you look at all of science done by humans as a whole; if you could image looking a high level time line of all human's major scientific discoveries, beliefs and falsifications of beliefs and you pretend that this was the career of a single scientist; I believe this single scientist would appeared to have operated exactly as Popper described. Popper described normal science in high-level sense, but it may not be accurate as related to individual scientists.

These two philosophers set out to answer very similar questions about the scientific method, what it was, and how it is carried out. They come to very different

results. Using Kuhnian terminology, they were using different paradigms, and perhaps their results are not directly comparable. With a more complex analysis, I believe it could be shown that they both describe aspects of how science is carried out. Kuhn described the more mundane day-to-day activities of an average scientist. Popper captured important aspects of science while giving a less accurate account of day-to-day scientific inquiry because the paradigm used did not consider the necessity of highly fast and immediately understandable communication of scientific knowledge.

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