Unnatural Selection:
Planck's Principle and Evolutionary Scientific Change
in the History and Philosophy of Science

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1. Introduction: On the Origin of Theses

I began this study with a simple quote from the renowned physicist Max Planck: "A new scientific truth does not triumph by convincing its opponents and making them see the light, but rather because the opponents eventually die and a new generation grows up that is familiar with it." It struck me as odd that I had not seen the quote before, not simply because of its refreshingly cynical attitude, but also its profundity in describing the nature of all ideas in history. It both historicizes and humanizes science, two aspects often ignored in more philosophical studies. I found the principle also had an evolutionary appeal to it with its sentiment of gradual change over time and the importance of the transference of ideas. Upon further research, Planck's Principle yielded a wide array of different issues present with an evolutionary theory of science and the vast amount of literature and debates on the subject. From here, I now realize that my journey has in many ways traced out the late philosopher, David Hull's own curiosity in science. A philosopher of biology, Hull had a brief encounter with Planck's Principle in 1978 in which he simply asked whether or not it was true, albeit as a misinterpretation of the principle. Ten years later Hull published a book entitled, *Science as a Process: An Evolutionary Account of the Social and Conceptual Development of Science*, in which, as one might assume from the title, he presents an evolutionary theory of science. Lastly, Hull devoted much of his later work dealing with evolution and the public perception of evolution. Another decade later, in 1998, Hull partnered with philosopher and evolution proponent Michael Ruse to publish a book on *The Philosophy of Biology*. Perhaps by more than mere coincidence, the topics in this thesis trail Hull's own studies.

The problem I ended with was one of broad significance to the history of science and public policy in general: what drives scientific change? Evolutionary theories of science appear to provide a nice answer and model and certainly there is much to learn from them. Evolutionary explanations reconcile different historical forces in a natural context; they blend both an internalist and externalist account. An idea may survive based on any relevant environmental selective criteria. Furthermore, scientific evolution creates a train of thought that leads to a metaphysical belief that evolution transcends biology, that science and technology are just extensions in human evolutionary development.

The attempt to balance internalist and externalist explanations also encompasses the similar dichotomy in historical narratives which emphasize the impact of either events or long-term movements. The problem then, is an old one, not just in the history or philosophy of science, but in history in general: how should we balance the actions of individuals or the magnitude of events against a cultural context or gradual movements? Stephen Toulmin, an early proponent of developing an evolutionary theory of science puts the question thusly, "By what processes do intellectual innovations originate, spread, and establish themselves within a scientific tradition?"[1]

Toulmin endorses an evolutionary conception of science to address this question, yet he is by no means the only one. Gerald Holton finds the comparison of science to biological organisms appropriate and cites four similar mechanisms that allow a comparison. Science, Holton argues, is continuous, subject to sudden mutations, has a multiplicity of effort, and has a selection process all analogous to biological mechanisms.[2] Other authors have proposed similar ideas, several of which will be discussed in this paper. Asking how ideas originate and take hold in science is a rather bold question that requires an elaborate answer and as philosophers

[1] Stephen Toulmin, "The Evolutionary Development of Natural Science," *American Scientist* 55 no. 4 (1967), 460
[2] Gerald Holton, *Thematic Origins of Scientific Thought* (Cambridge: Harvard University Press, 1973), 392-392.

proposing an evolutionary answer to the question will often have to grapple with problems the analogy poses.

Therefore, within this question, this paper further asks how the history and philosophy of science has grappled with these issues through the analogy of evolution. The term evolution has been used in the vernacular for centuries and was first used in the biological sense by Charles Lyle in 1832. Darwin had even shied away from using the term in *On the Origin of Species* because its earlier use had a strong connotation of progress.[3] Evolution was only later popularized as the name for the theory by Herbert Spencer and others which may explain some of the confusion already. Evolution is now prolific in the vernacular, with its use being applied to nearly everything. If the internet is to be trusted as a representation of culture and the vernacular, the auto complete search on Google turns up the following end terms for the search, "evolution of…," "dance," "man," "the hipster," and "smooth," in that order. One may notice that the biological sense of evolution is really only present in one of the search terms, assuming that hipsters are not a distinct new species. The same search in Google books reveals similar results with titles like, "The Evolution of God," "The Evolution of Obesity," "The Origin and Evolution of Viruses," and "The Evolution of Grammar." Again, we see only one biological sense of the term. Evolution is instead used in a way that describes change or the history of something in a way that either traces it back to the origin or catalogues the changes over time. Given its own evolution, this meaning makes sense; the word still maintains its connotation of progress and development and its general metaphorical meaning of change. Most of the uses of evolution applied to explain the development of something have been used in this sense and need not worry this study. In the history and philosophy of science evolution has often been used to

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[3] Online Etymology Dictionary, http://www.etymonline.com/index.php?term=evolution (last accessed Dec. 13, 2011).

describe the change in beliefs or methods over time in this much more metaphorical way. However, biological evolution as a metaphor, and sometimes more, is also often used to describe scientific change in quite a serious way. Toulmin's answer to his question above was to look for an evolutionary theory of science. He concludes, "The idea that the historical changes by which scientific thought develops frequently follow an 'evolutionary' pattern needs to be taken quite seriously; and the implications of such a pattern of change can be, not merely suggestive, but explanatory."[4]

This thesis also examines the rigidity of belief in society as it is intimately tied to issues of evolutionary science. In biological evolution information is passed from one generation to the next through gene replication. In the evolution of science it is not that simple, theories persist because the new and contemporary scientists believe and support them. Belief, while often inherited, is subjected to much more complex mechanisms best left to psychologists, philosophers, and others. Scientific belief on the other hand has been examined and modeled with attempted demarcations from regular belief. Often these explanations state that science is a rational process and that any person following such a rationality, regardless of their background or upbringing will come to the same conclusion about the natural world. Resistance by scientists to a new, strongly supported, theory is seen as unscientific and often condemned. Science idealizes malleability of belief, of being able to change one's position given new evidence and yet this often does not happen. Scientific controversies emerge and even when a consensus is reached by the scientific community, some opponents may very well hold out and garner a following among the next generation. Science may be distinguished from regular belief in its malleability yet it still succumbs to basic human foundations. Examining the mechanisms

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[4] Toulmin, 470.

underlying scientific change requires an analysis of how ideas are transferred and received. Whether or not scientific communities readily embrace new theories will determine the nature of how, or if, science truly evolves. Furthermore, we can see what happens when scientific belief clashes with normal or public belief. Despite some radical objections, one can argue that because of certain philosophical commitments, scientific epistemology is easily demarcated from the public epistemology, one is supposed to obey the laws of rationality, the other is supposed to obey the laws of mass psychology. I think one can maintain this position so long as one adds the caveat that scientists also count amongst the public and are subject to psychological boundaries as well.

These two issues merge in what is known as Planck's Principle, a statement by Max Planck in his *Scientific Autobiography*. His quote is not just about people being stubborn but also about the greater evolutionary nature of science. It is about the transference of ideas in an evolutionary sense rather than the duplication of ideas in some psychological sense. This thesis proposes the hypothesis that if the philosophy of science insists on an evolutionary framework for scientific change, then Planck's Principle provides a useful interpretation of the transfer of ideas within such framework. Through the merging of issues within the history and philosophy of science, the principle bridges a gap between history and philosophy in the question of what drives science. Furthermore, it removes metaphor and analogy from an evolutionary conception of science – something that proves quite troublesome for many of the authors cited in the paper. This paper will begin with a look at exactly what Planck meant by his statement and how it has been misinterpreted. I will instead present an interpretation of Planck's Principle that sets up an evolutionary view of science one that exists as a truism and balances the forces in Toulmin's problem. The next chapters will focus on evolutionary conceptions of science from some prominent philosophers in science. The hypothesis of this thesis rests first on the assumption that evolutionary analogies to scientific change are a proper direction of study. These philosophers contrast fairly highly with one another in their ideologies, yet all find use in the evolutionary analogy. Therefore we must ask what it is about science that inspires such similar comparisons. Chapter seven will address this question, placing an emphasis on universal principles embodied in both a metaphorical use of the word and natural selection's historical ties to economic theory. The paper will then focus its attention more on the issue of rigidity of belief in evolutionary theories. Chapter eight deals with the issue of age as an important factor in transfer of ideas, even while it acts as a sociological, and perhaps even psychological, obstacle. Chapter two will show that age is not a relevant factor in Planck's Principle, yet this chapter examines what role age plays in evolutionary theories. The next two chapters address evolutionary theories in two seemingly opposite studies, multiple discovery and scientific controversy. Both studies rely on an evolutionary structure. Multiple discovery invokes Toulmin's idea of using the evolutionary analogy to balance externalist and internalist interpretations of science while theories about scientific controversies stress closure which ultimately takes the form of Planck's Principle. The paper will conclude with a brief examination of the theory of evolution itself. This theory, as it exists as a public controversy, will be useful for addressing the same overlap between the evolution of the theory and the rigidity of belief. While Planck's Principle may exist as a truism at some level, the public acceptance of evolution shows that it far more represents public or normal belief as opposed to scientific belief.

2. Planck's Principle, Its Origin, Context, and Misinterpretation

In his 1949 Scientific Autobiography, Max Planck stated "A new scientific truth does not triumph by convincing its opponents and making them see the light, but rather because its opponents eventually die and a new generation grows up that is familiar with it."[5] Since then scholars have come to refer to this statement as Planck's Principle and have interpreted it to mean several different things in the philosophy of science. Some regard it as an age issue in science, seeing the older generation as more stubborn and likely to cling to their wrong ideas while others juxtapose this stance with Karl Popper's notion of falsifiability. While these are not mutually exclusive interpretations, each serves a purpose, the former to breakdown variables in the process of scientific discovery and the latter to contrast ideologies in the philosophy of science. This paper will present another interpretation of the Planck quote, one that hopefully does it more justice in its original context and also recognizes the statement as a truism, albeit an important and oft neglected one.

The process of scientific discovery may often be explained through different constraints. People could not observe the moons of distant planets before the invention of the telescope nor could relativity theory be cognitively born without industrial clocks and fast railroad transportation. These are merely technical constraints yet there are also constraints in cultural and governmental predilections, financial resources and human resources. However, what Planck's quote illustrates is the importance of time as a limited resource. Scientific debates are not explored ad nausea with all the evidence weighed and evaluated and then argued point by point. Dialogues can only last so long because people are constrained in their time, and not merely their working hours, but by their hours on this earth. New "scientific truths" stand the

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[5] Max Planck, *Scientific Autobiography* (New York: Philosophical Library, 1949.), 33-34.

test of time; they stay around after both their original opponents and proponents are long gone. Furthermore, Planck's statement assigns priority to an evolutionary rather than a conversion mechanism in scientific change, where opponents do not convert to adhere to other theories but rather simply die off. This notion also implies a type of reproductive mechanism that allows theories to be passed from one generation to the next. This interpretation also need not exclude the others. Earlier work on this subject has focused more attention on the other interpretations of Planck and serves as a proper starting point for how such interpretations may be used in analysis.

Often Planck's quote is lumped together with others from Darwin, Huxley, and Lavoisier who all in some way express a concern about age and science.[6] In Lavoisier's Reflections on Phlogiston he remarks that "the human mind gets creased into a way of seeing things," and laments that older scientists cling to their ideas while rejoicing in seeing young scientists accept his own theory.[7] Similarly Darwin placed his hope in youth explaining at the end of his Origin of Species, "I look with confidence to the future, to young and rising naturalists, who will be able to view both sides of the equation with impartiality."[8] Lavoisier and Darwin faced an entrenched opposition to their own theory and regarded scientific truths as surviving not necessarily through education but by shedding bias. For them this bias was a product of age, a certain inelasticity of an older mind. "Darwin's Bulldog," T.H. Huxley even went so far as to denote a person's 60th birthday as their "day of strangulation," in order to not only save others from their resistance to

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[6] See Hull et al., "Planck's Principle," *Science*, *New Series* 202, no. 4369 (Nov. 17, 1978):. 717-723; Levin et al., "Planck's Principle Revisited," *Social Studies of Science* 22, no. 5 (May 1995): 275-283; Thomas Kuhn, *The Structure of Scientific Revolutions*, (Chicago: Chicago University Press, 1970), 151; and Bernard Barber, "Resistance by Scientists to Scientific Discovery," *Science, New Series* 134, no. 3479 (Sep. 1, 1961): 596-602.
[7] Antoine Lavoisier, in *The Edge of Objectivity* ed. C. Gillespie (Princeton: Princeton University Press, 1960), 232.
[8] Charles Darwin, *On the Origin of Species* (Cambridge: Harvard University Press, 1966), 481-482.

new ideas, but also to preserve their own earlier achievements.[9] Of course, Huxley himself was granted a 10 year extension.[10]

These reflections are summed up also in popular sentiment, for instance, in the English idiom, "you can't teach an old dog new tricks." Although perhaps science itself can help overcome this adage. The French philosopher of science, Gaston Bachelard even argues that the practice of science itself makes the mind younger by breaking it away from any prejudices formed by age. However he too acknowledges a sentiment that "great men are useful to science in the first half of their lives and harmful in the second."[11] These expressions seem quite natural in any society that views change positively, especially if change is seen as progress. A culture that views knowledge as progressing, that we know more now than we did back then, should naturally view the latter part of life as trending away from the changing cultural milieu. Since at least the Enlightenment, Western societies have adopted this view of progress as it has driven curiosity and invoked the connotation of the future as the yet-undiscovered. The future would not be a recombination of what we already know from the present, not a simple redrawing of political boundaries or redistribution of resources, but a genuinely different place, not unrecognizable, but not familiar either. For most the vision of the future depends on science, it is its driving force and therefore may itself create such generational prejudices.

Of course this is not to say that Western culture has turned its back on the emphasis placed on wisdom; if societies progress then people can surely accumulate knowledge and experience as well. Expertise is essential for any well developed discipline and for trades such

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[9] L. Huxley, *Life and Letters of Thomas Henry Huxley* (New York: Appleton, 1901), 2: 117.
[10] See the letter on occasion of his 60th" from M. Foster in *Life and Letters of Thomas Huxley*, 257. Foster notes that even though Huxley has reached his "day of strangulation" he says that it would be ok to defer the decision for "say, at least ten" more years; Huxley died a month and a half after his 70th birthday.
[11] Gaston Bachelard, *The Formation of the Scientific Mind,* trans. Mary McAllester Jones (Manchester: Clinamen Press, 2002), 25.

as medicine or law it is indispensible. Instead, this ageist sentiment manifests not against garnering wisdom and expertise, but around the new and the inability at adaptation. The comments from Lavoisier, Darwin, and Huxley do not lament the disappearance of youthful curiosity with age, but the appearance of a resistance to new habits or ideas. Planck too shares this feeling regarding the stubbornness of belief, yet before discussing the true meaning of Planck's principle, we should ask whether this interpretation is true.

Several papers have addressed this question, framed explicitly as whether a scientists' age makes them more reticent to accept new scientific findings. They test the hypothesis that the older a scientist is, the more likely they are to resist, or to simply not convert. In Hull et al. (1978), the authors examine the Darwinian revolution to test Planck's Principle noting that the contemporary evidence about a decade after Darwin's *Origins* posited that nearly all young scientists had been converted within that decade.[12] They specifically interpret Planck's Principle in their subtitle as "Do younger scientists accept new scientific ideas with greater alacrity than older scientists?"[13] The authors examined the beliefs of 78 British naturalists in the ten years immediately after the publication of the *Origin of Species* noting their ages and when they first accepted Darwinism. They essentially measure a rate of conversion for these scientists attempting to find a pattern in how long it took a naturalist to convert and become, at the very least, a passive proponent of evolution by natural selection. The authors end up concluding that while "age is a relevant factor in distinguishing between those scientists who accepted the evolution of species before 1869 and those who did not," while also noting that, "less than 10 percent of the variation in acceptance is explained by age."[14] More importantly the authors

[12] Hull et al., "Planck's Principle," *Science*, *New Series* 202, no. 4369 (Nov. 17, 1978):. 717-723.
[13] Id., 717.
[14] Id., 722.

acknowledge the trouble in describing a scientist as a convert remarking that if the acceptance of the entirety of Darwin's theory made someone a Darwinist then few could be counted as converted; most scientists instead selectively accepted the most basic or relevant points.[15] Given all the considerations in this simple case study, the authors finally note that "older scientists were as quick to change their minds as younger scientists."[16]

A follow-up to this study in 1995, entitled, "Planck's Principle Revisited: A Note," authors Levin et al. draw on a hypothesis put forth by Peter Messeri regarding the controversy over plate tectonics. Messeri argued that at the beginning of a controversy surrounding a new theory, older scientists will be the first to accept it as they can afford to take more risks than their younger colleagues. Then, as a theory diffuses, younger scientists will be more likely to accept it. Levin et al use Messeri's hypothesis to test whether such a pattern applies to Darwin's acceptance in Britain and use Hull et al's data set of the 78 naturalists. Their conclusion comes quickly and is fairly straightforward, "age has essentially no influence on the probability of a scientist's accepting Darwin's theory of evolution."[17] These authors again find little if any relevance of age in conversion to a new theory. Of course these conclusions are based on one data set and examine one highly controversial theory with concerns that transcend merely the scientific. Messeri's plate-tectonics study supported his hypothesis as I am sure other studies would as well. It is nearly impossible to interpret Planck's statement as a testable generalization of age in science as each case is so different. Furthermore, if the social construction of science is to be taken the least bit seriously then age will only make a difference when tied to different cultural contexts and therefore the bias of a new theory will not necessarily be towards youth.

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[15] Id., 721.
[16] Id.
[17] Levin et al., "Planck's Principle Revisited," *Social Studies of Science* 22, no. 5 (May 1995): 279.

With the collapse of Deutsche Physics after WWII, one could argue that the older scientists might be the first to accept newer theories contradicting those held more firmly by their younger colleagues. If younger scientists are taught to filter their science in ways that an older generation was not, the impressionablism of youth could itself be a problem. All in all, whether or not age is relevant must be taken on a case by case basis.

One other case that has been briefly examined is that of Planck himself and his colleagues who formed the foundation for his statement, namely Ostwald. John Blackmore, in "Is Planck's 'Principle' True?" a fairly truncated discussion from 1978, argues that "Planck was an exception to his own 'principle.'"[18] Planck himself came to accept a theory that he had opposed for twenty years, and as Blackmore points out, so too did Helmholtz and Ostwald. Blackmore strongly concludes that, "In short, Planck's 'principle' was not true for Planck, Helmholtz, Ostwald, or Heisenberg in the most critical aspects of their work, and it is doubtful if it is true at all in unqualified form or even in a qualified way for men of strong intellectual integrity who insist on carefully examining each relevant theory and the pertinent experimental data."[19] Of course this last phrase certainly acts as a qualifier to almost make any such cases highly improbable. Blackmore's description does however provide an example of what people think science should be, "men of strong intellectual integrity" objectively weighing data to decide on the theory. If his interpretation of Planck is correct then he would simply be arguing against Planck's vision of science based solely on the profile of science which will degenerate into the old internal versus external debate. Yet if this is what Planck was really saying, wouldn't he have realized that his own autobiography contains anecdotes which explicitly

[18] John T. Blackmore, "Is Planck's Principle True?" *The British Journal for the Philosophy of Science* 29, no. 4 (Dec., 1978), 347.
[19] Id.

contradict him? One would think as much as long as these authors have correctly interpreted Planck's statement. But what was Planck actually saying in his Scientific Autobiography? Was he putting forth a hypothesis on age, taking a purely externalist position, or something altogether different and benign?

As one might assume, the short answer to these questions is an emphatic no. After an even shallow reading of Planck's autobiography, it becomes clear that what has become Planck's Principle is quite far removed from what Planck was actually saying. Blackmore's digression has already shown that Planck's Principle, defined as either a more youthful acceptance of new theories or as a resistance to conversion, did not apply to Planck himself. Blackmore also argues that the statement really didn't mean much to Planck but was "a mere *obiter dictum,*" and in the grand context of his autobiography, Blackmore appears to be mostly correct.[20] The statement may be characterized first and foremost as just a passing reflection; or a comment borne out of the author's frustration. This is evidenced by the discussion leading up to the statement in which he describes his role in the debate between Boltzmann and Ostwald over Energetics. While Planck describes himself as a main proponent of Boltzmann, he also states that Boltzmann did not act favorably towards him as he had not supported Boltzmann's atomic theory until much later. Yet Planck hardly describes his own switch as a conversion but merely a reaction to a deficiency in Boltzmann's theory that was not corrected until later.[21]

Even though Planck's comment specifically addresses this controversy it is quite easy to find his own frustration leading to such a conclusion in the preceding pages. When commenting on the acceptance of his own theories Planck makes no doubts about his feelings: "It is one of the most painful experiences of my entire scientific life that I have but seldom…[succeeded] in

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[20] Id.
[21] Planck, 32-33.

gaining universal recognition for a new result, the truth of which I could demonstrate by a conclusive, albeit only theoretical proof."[22] When he did see his theory vindicated it was through the indirect route of acceptance of Boltzmann's atomic theory which Planck considers "annoying."[23] From these comments we can certainly see the cynicism present in his "principle" which serves as a nicer, or perhaps more cynical, way of calling his former peers stubborn.

For these reasons it is hard to see the comment as much more than a passing remark, yet for a man always concerned with the absolute, he attributes much more significance to this statement than an "obiter dictum" deserves. In fact, Planck attributes the significance of this entire period of his scientific life to this realization and to the hard truths he was forced to learn from it. The Energetic controversy for Planck was not an accomplishment but rather a learning experience. He writes, "This experience gave me also an opportunity to learn a new fact – a remarkable one, in my opinion."[24] He then states what we now know as his principle and immediately following writes, "Otherwise the controversies just mentioned held comparatively little interest for me."[25] So while it is still best to characterize the statement as a passing remark, it does hold autobiographical importance. Planck was able to pinpoint his turn to a more cynical view of scientific discovery brought about from some of his first experiences dealing with peers in his field. As Blackmore has also argued, the attribution of such characteristics to scientists goes against such an ideal in science and while he might have been making a philosophical point about science, Planck was also likely painting his opponents as unscientific and failing to live up to such ideals.

[22] Id., 30.
[23] Id., 30-31.
[24] Id., 33.
[25] Id., 34.

From this vantage we may now give Planck's statement a more appropriate interpretation, not one based on age as Hull et al. and others contend, but one based on conversion and education. Indeed, Planck never mentions whether the age of scientists matters at all. In fact, one could even argue that the phrase "its opponents *eventually* die," is indicative that age has absolutely no bearing on the acceptance, only the passage of time. If one were to nitpick, the German word allmählich is used in Planck's original description. This word's connotation further supports the non-ageist sentiment in Planck in that it means "gradually," or "bit-by-bit," indicating that he did not even necessarily see it as a generational process but instead as something occurring across generations. It is this passage of time that is often neglected in the philosophy of science; science is after all a human activity and thus subject to basic human biological laws like death. In this sense Planck's quote comes off more as a cynically worded truism. Regardless of any additional meaning Planck and others have wanted to attribute to it, the statement portrays a change in belief that could happen absolutely no other way. Well, one other way – full conversion, or what Planck referred to as "universal acceptance." While I would hesitate to say that this never happens I find it difficult to believe that any new theory in today's rather populous and diverse scientific community would be able to convert everyone holding a conflicting theory before their death. So then we can safely assume that not everyone will be converted for any new scientific truth and therefore the only possible means of its survival is the theory being accepted by a new generation. The opponents of the theory may also pass their theory on but then it still remains an issue of that next generation's proponents and opponents and so on until closure, at which point the theory can be called a "new scientific truth" in Planck's sense.

Thus Planck's statement is a truism, yet an important and often neglected truism. Even Planck calls it a "remarkable fact" which raises the question of why a truism should appear as a "remarkable fact" to one of the foremost men in science? The most likely explanation is found in Planck's cynicism surrounding his failed efforts to promote his theories. Planck began his scientific career at the height of the positivist movement and in a time when science was taken as absolute and objective. If there was ever a controversy then further testing or theorizing would make it very clear which one was right. As quoted earlier, he complained that his theories did not meet universal acceptance even though he could demonstrate their truth. Perhaps the greatest perpetrator of cynicism then is blind optimism or the idealization of, in this case, science. When science is idealized or abstracted to such a degree that it ceases to be a human activity but an ethereal process, a truism such as the one expressed by Planck is seen as something new, an alternative to the ideal.

Returning to the Hull et al article, we can now see the mischaracterization of Planck's statement. The authors assert that, ""If Planck is right, reason, argument, and evidence do not play a very large role in scientific change." How anyone even slightly familiar with Planck could attribute this sentiment to him is a mystery. He was not saying that evidence and reason are not responsible for new scientific truths, but that not everyone can be convinced. This statement also makes little sense in an article hypothesizing that younger scientists are more likely to be persuaded by such reason, argument, and evidence. Planck himself did not follow this rule, nor did his contemporaries who provided the impetus for the remark in the first place. Furthermore, Hull et al use their final remark to conclude that "the connection between age and acceptance is not as important as people such as Max Planck have claimed."[26] It is perfectly fine to investigate

[26]Hull et al., 722

whether age does affect a scientist's theory choice, but the authors are mistaken to attribute this sentiment to Planck. Furthermore, Planck's statement, while saying nothing about a scientist's age, also says nothing about a scientist's willingness to convert to a rival theory. In an extreme reading of Planck no original opponents to a theory will convert and the only change will be through the indoctrination of students or "the new generation… that is familiar with it." These students are not more willing to accept the theory because they have weighed it against its rivals, but because it is the theory they have been told is correct.

Perhaps this discussion will do no more than expose the black box surrounding Planck's Principle and at the very least vindicate Planck as a philosopher of science. Planck's remark has been misinterpreted and reformulated into Planck's Principle and unfortunately Planck himself has had no recourse to correct it as scholars have only taken note of it posthumously. Yet the poorly-named Planck's Principle as it is now codified is not completely without merit. As shown above, this principle that young scientists are more willing to accept new theories than older ones does resonate strongly with people, or at least people in the first half of their lives and on the most basic level. Especially given the increasingly more technical aspects of education and socialization, the youth at present are more likely to see the older generation as out-of-touch with their culture and vice versa. So while each scientific controversy will yield its own conclusion on whether or not age matters it's difficult to deny a strong and growing sentiment of ageism. Furthermore, while it is dubious to link age to acceptance of new theories, age does of course play a role in science. We do not see an abundance of 20 year old professors and 60 year old students. Age is relatively important in determining the mechanisms through which ideas are transferred from one generation to the next.

We should also discuss what is meant by generational? A generation in the common social use is nearly impossible to specifically define in terms of age. Where would one end and another begin? Instead there are generational slices depending on the dimension being analyzed. When presented in a technological sense, you may say that we are now seeing the first generation raised on personal computers, but this does not apply to all children of a certain age range yet only those raised on computers. For instance, generations in the United States are defined several different ways. There was the "Greatest Generation," those that grew up in the Depression and served during WWII; this definition places a strong emphasis on sacrifice as a shared feature. The "Baby Boomers" followed, these denoted, as the name implies, by comprising a population boom after WWII. The more recent "Generation X" is denoted by disillusionment and pessimism around a struggling economy, and "Generation Y" was labeled before it even existed and hasn't really been clearly defined other than being after X. Generations are defined in retrospect based on some shared characteristic or a large event that impressed something on the collective psyche. Therefore in science generations emerge through new discoveries, falsified theories, or external cultural pressures. In this paper, generational change is used as one form of evolutionary scientific change based on the mechanism in Planck's Principle. As the principle is essentially a truism, generational change also literally exists as such when generations are themselves defined by theory change. Instead the mechanism should be interpreted as a gradual replacement of one form of belief to another over time due to the death of opponents and the recruitment of youth. Age dynamics are therefore relevant in spite of the casual misinterpretation of the principle.

3. Planck's Principle in the Philosophy of Science

Planck was not the first to note the generational aspect of science nor did his remarkable fact go unnoticed. Philosophers of science before and after Planck have, sometimes without directly recognizing it, provided a scheme to explain how ideas sift through generations. The idea that science flows through time rather than merely building upon itself is often taken for granted, yet in other cases science is removed from time and theories are rationally reconstructed. Thomas Kuhn, the prolific philosopher of science, draws heavily from Planck's truism and in many ways mirrors Planck's sentiment in his arguments. Kuhn presents the contrast between Planck's notion and Karl Popper's falsifiability by historicizing scientific change and introducing it within a sociological realm. However, Popper, writing his foremost work *Logik der Forschung* in 1934 espoused ideas that share some key characteristics with Planck. Popper's doctrine of falsifiability was later reinterpreted by Donald Campbell in the form of evolutionary epistemology which Popper fully supported. Another prominent philosopher, Paul Feyerabend also follows a similar line with his methodological anarchism which may easily be expressed as a free market of ideas. These authors provide rather relatable concepts to describe the passage and transfer of scientific ideas from one generation to the next and examining these core pillars of the philosophy of science will validate the importance in Planck's truism and also expose areas in the philosophy of science that outright ignore such conclusions. Lastly, we should consider some of the multitude of other approaches to the question of how ideas change or grow in society. Logicians have provided complex models of beliefs and their expansion and contraction, psychologists have examined why and how people change their minds, and sociologists have uncovered means by which people are convinced through external forces. Often these approaches will rely on evolutionary metaphors and each will appropriate and compartmentalize the relevant mechanisms for their analogy.

I have chosen these three philosophers, Kuhn, Popper, and Feyerabend for some obvious and some not so obvious reasons. To begin, the names have high recognition even outside the philosophy of science. Karl Popper and Thomas Kuhn specifically are often cited as the founding fathers of the history and philosophy of science with Kuhn often cited as the father of disciplinary history of science. Popper's works did not stop at the philosophy of science but covered a range of other philosophical topics with his book of political philosophy, *Open Society and Its Enemies,* rivaling *Logik der Forschung* for his most famous work. Similarly Kuhn's work, primarily the ideas set out in *The Structure of Scientific Revolutions,* have transcended mere issues in the philosophy of science. The business and political worlds have appropriated his ideas and Kuhn's conception of a paradigm is extensively used in the vernacular now. Paul Feyerabend, while not as well known as Kuhn or Popper, is still a giant in the philosophy of science and particularly well-known for the perceived extremism in his argument for epistemological anarchism. His most famous work, *Against Method*, serves as an argument for the non-existence of any universal epistemological laws and constitutes part of a dialogue with fellow philosopher Imre Lakatos.

Furthermore, French philosopher of science Gaston Bachelard offers a philosophical psychological sketch of science that departs from the others in terms of his philosophical approach and will be explored relevant to the age considerations in Planck's Principle. He provides a unique consideration of science, curiosity and age in his work, *The Formation of the Scientific Mind*. His approach may in fact be the furthest removed from reality yet provides the most insight regarding how science conforms to a lifespan and vice versa. Bachelard, while not often placed in the canon of modern philosophy of science, is quite prominent in French philosophy and came to influence Michel Foucault and Thomas Kuhn.

Each of these philosophers has posited some mechanism for the progress or survival of ideas, yet each approach the problem in a unique way. Kuhn uses an aspect of generational change to support his model for scientific revolutions. Indeed, simply by using the term 'revolution' he historicizes scientific change. Popper, while avoiding discussion of generations, creates a model of the evolution of ideas, thus explaining how ideas survive. Feyerabend sets out to both vindicate his personal philosophy and describe the chaotic yet natural way ideas take hold and survive and Bachelard posits how science minimizes such generational hindrances. This diversity of approaches to the same issue are all related by Planck's truism and provide a different vantage through the minutiae that such a process entails. The way that these authors acknowledge the generational or evolutionary character of scientific activity helps to show its importance in accurately understanding how science itself evolves and just how literally we should take that.

4. Kuhnian (R)evolutions

Of all the authors, Kuhn's argument in *The Structure of Scientific Revolutions* (SSR) most closely resembles the sentiment expressed by Planck, and as such, it is no surprise that he is the only author of the three to reference Planck's statement directly. Kuhn's approach may inherently be more accepting of Planck simply by its historical character and the methodology that assumes time as a factor. A revolution, as Kuhn uses it, is an event in history which can be called so because the relevant characteristics present before it have been thoroughly altered afterwards. A revolution in science thereby becomes a narrative with conflict and closure, the mechanism of which is bounded by the human biological clock. Throughout the work Kuhn comments on the generational aspects of scientific change and controversy resolution, yet his ideas are best understood through a look at what comprises his "structure of scientific revolutions." Furthermore, his focus on the scientific community reflects Kuhn's sympathy for sociological issues rooted in human scientific activity.

The relevant concepts Kuhn outlines in SSR also comprise some of the key contributions he has made to the lexicon. These notions are paradigm, or a set of shared beliefs and practices of a scientific community, incommensurability, or the inability for reconciliation between two competing paradigms, and his analogy of the gestalt conversion where a person may switch from one paradigm to the other. Kuhn's choice of the revolution analogy to describe scientific change builds off the conception of the original Scientific Revolution first proposed by Immanuel Kant in his Enlightenment description of "a revolution in mode of thought," thus giving birth to the historiography of the Scientific Revolution.[27] In SSR Kuhn focuses on several revolutions in science, adding Lavoisier, Newton, and Einstein to his earlier work and analysis of *The Copernican Revolution* that was used as a stepping stone to the book. These intellectuals represent "turning points in science" where one way of thinking was overthrown and replaced by a new paradigm. Thus the description of revolutions is also a narrative of scientific controversy which Kuhn views as endemic to science, contending that any theory will never be able to explain "all the facts with which it can be confronted."[28] Controversy functions in a see-saw manner, with any theory not even needing a rival to expose its own anomalies and eventually collapsing when a rival does appear with greater problem-solving ability. Yet Kuhn is primarily

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[27] H. Floris Cohen. *The Scientific Revolution: A Historiographical Inquiry*. (Chicago: University of Chicago Press, 1994), 25.
[28] Kuhn, 18.

focused on the transition between periods of normal science, even with their points of controversy.

While Kuhn never really defines what constitutes a paradigm (even when prompted), his examples of the various revolutions provide a basic structure that is at the very least useful to describe certain schools of thought. Therefore, the notion of a paradigm is perhaps more useful in the social sciences and business disciplines where ideology may play more of a role. In economics it would be much easier to classify the Austrian school, which has its own publications and specifically libertarian political entanglements, as a paradigm than to describe a Copernican paradigm with its scattered and myriad proponents. Granted some of this discrepancy is merely a product of discipline formation and the diverse yet structured nature of academia in the twentieth century. More relevant to the discussion presently is Kuhn's description of paradigms as a scientific community as any such community will either shrink or grow, at least partly due to natural causes. New scientists, often younger ones fresh in the field will be incorporated into the community as older or less fortunate younger ones will leave as their time on earth ends. These scientific communities, by comprising part of a paradigm are thereby entrenched in supporting a particular theory. Because Kuhnian paradigms are rooted in the scientific community, Kuhn also draws common sense conclusions about the role of human nature in such communities. Kuhn's emphasis on the community helped to separate him from other philosophers of science and explains his influence on later studies in the sociology of science. Early in SSR Kuhn digresses to focus on the role of community in what certainly resembles a sociological approach, examining, "how the emergence of a paradigm affects the structure of the group that practices the field."[29] When discussing the disappearance of one

[29] Id., 18.

paradigm and the conversion to another Kuhn notes, "In part their disappearance is caused by their members' conversion to the new paradigm. But there are always some men who cling to the old views."[30] Rooting the notion of paradigm in groups that constitute them also roots science as a human activity rather than a process of rational heuristics as both Popper and logical positivists before Kuhn had posited. Kuhn dedicates his own theory to tracing the structure and composition of these communities over time and therefore must confront the tautological mechanism embodied in Planck's statement.

Kuhn's notion of a paradigm is controversial, yet it has been picked up in other areas due to its easy application and use in the vernacular. The same cannot be said about his notion of incommensurability. This idea follows from Kuhn's contention that revolutions are changes of world view which he outlines in chapter ten of SSR. Scientists in one paradigm, with their shared beliefs, practices, and definitions, are also within a different world than those in a competing paradigm and similarly, "after a revolution scientists work in a different world."[31] Other authors have also implied an age hypothesis based on incommensurability.[32] If a change in paradigms is a change in world view then those younger scientists growing up familiar with the theory will also be living in a different world incompatible with that of the older generation.[33] Kuhn embodies this concept in the analogy of the duck/rabbit gestalt image where looking at the illustration one way will yield a duck and the other a rabbit. Incommensurability arises because while someone can see either a duck or a rabbit, they cannot see both at the same time. Scientists in one paradigm lack the ability to understand how a competing theory functions in the terms of their own paradigm. Language is given a special importance in scientific progress as

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[30] Id., 18-19.
[31] Id., 135.
[32] Hull et al., 718.
[33] Id.

meanings are re-interpreted under a new paradigm. Incommensurability comes off as striking because it would essentially confirm the most extreme interpretation of Planck's statement – that people cannot be convinced, or it is extremely difficult to do so, given the irreconcilable differences between the two paradigms. Someone from one paradigm cannot be convinced by someone from another because all arguments for the new paradigm would not make sense within the old paradigm. However, Kuhn does address how such conversions would occur and uses the gestalt analogy to describe such occurrences.

The gestalt switch from one paradigm to another comprises the analogy at the heart of Kuhnian scientific progress. It is the mechanism which accounts for revolutionary scientific activity and implies the overthrow of one theory rather than a modification of an existing paradigm during periods of normal science. While Kuhn argues that the psychological gestalt experiments can provide a glimpse into paradigmatic scientific thought, he also acknowledges the limitations of implicating too much from it. Kuhn writes, "They do display characteristics of perception that could be central to scientific development, but they do not demonstrate that the careful and controlled observation exercised by the research scientist at all partakes of those characteristics."[34] Instead, Kuhn notes the key difference between such experiments and the activity of scientists. In a gestalt experiment the observer may easily step back and be able to observe both images as one illustration, thus they have recourse to an external standard.[35] Within science however, there can be no such recourse Kuhn argues. Therefore people are stuck seeing either a duck or a rabbit simply because that's all they know.

These basic characterizations of paradigm, incommensurability, and the gestalt analogy present the framework for Kuhn's own discussion of the role of generational change in scientific

[34] Kuhn, 113.
[35] Id., 114.

progress. He foreshadows as to how to approach generational change throughout SSR and addresses the issue directly in his last two chapters. In this discussion Kuhn also invokes Planck's Principle and the age effect. Like other authors discussing Planck, Kuhn associates his sentiment with other scientists like Darwin.[36] He cites Darwin and Planck specifically when answering his own question of how scientists come to make the switch from one paradigm to the next pointing out that often they do not.[37] He further notes the self-evident nature of such sentiment saying that they are "too commonly known."[38] Like Planck, Kuhn sees this as an inconvenient fact of science and attributes this reluctance to convert not to mere stubbornness but to lifelong resistance built from living in a different world. It provides a less cynical view than Planck basing it more on innate human traits rather than personality flaws. Kuhn's emphasis here is important because it again illustrates the strong sentiment of the rigidity of belief as an unchangeable aspect of human nature. However, Kuhn does add a caveat, albeit in a distanced and passive way, labeling those resisting such revolutionary scientific change as ceasing to be involved in science anymore. He writes, "The man who continues to resist after his whole profession has been converted has ipso facto ceased to be a scientist."[39] Kuhnian science both accepts resistance and condemns it. This latter quote also gives a rare view from Kuhn about what science should be ideally, and departs from the main historical thrust of the rest of the book.

It is Kuhn's contribution to the establishment of the sociology of science that is embodied in an analysis that places science not in an abstract philosophical or psychological realm, but in a social one. So what drives scientific change according to Kuhn? Well if progress occurs

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[36] Id., 151.
[37] Id., 150.
[38] Id., 151.
[39] Id., 159.

through revolutions, then such change is brought about by switching paradigms. The only way a paradigm switch can occur is when scientists begin conglomerating in the new paradigm. Planck's principle is reformulated by Kuhn within his own theory rather bluntly as "Conversions will occur a few at a time until, after the last holdouts have died, the whole profession will again be practicing under a single, but now a different, paradigm."[40] He specifically elaborates on his own conception of scientific evolution in the last two chapters of SSR, however Kuhn does not present his analysis through such an approach so we may only reformulate the details of his own theory by taking his hints and the context outlined above.

We should begin by discussing Kuhn's treatment of the ambiguity in the interpretation of Planck's quote to mean both the greater flexibility of younger scientists to convert to another paradigm as in the age hypothesis and the more literal interpretation of a younger generation simply being indoctrinated with the new theory. Kuhn chooses the latter as both implied by his notion of paradigm and explicitly stated in his juxtaposition with the social sciences. In the social sciences the student "has constantly before him a number of competing and incommensurable solutions to these problems, solutions that he must ultimately evaluate for himself."[41] He makes this inference based on the educational differences between both studies and ultimately cites the educational structure as the backing for his own structure of scientific advancement. Education in the natural sciences comes in the form of textbooks which condense the work previously done in the field and which, Kuhn contends, provide a "narrow and rigid education."[42] Kuhn sees textbook education as central to the development of paradigms and the generational transfer of ideas. They codify a paradigm and represent closure of a scientific

[40] Id., 152.
[41] Id., 165.
[42] Id., 166.

revolution. Moreover they dictate the puzzles that the paradigm should confront and which types of questions are appropriate. Textbooks emerge from the current scientific community and are endowed to the next, not by choice, but by necessity. However, in the broader context of asking whether students are indoctrinated or choose a theory, Kuhn also adds another caveat. While students do not choose between competing paradigms, they are more likely to split from any paradigm in crisis. Kuhn explains that "they are men so young or so new to the crisis-ridden field that practice has committed them less deeply then most of their contemporaries to the world view and rules determined by the old paradigm."[43]

The question of indoctrination versus theory choice is easily answered by Kuhn, yet the problem of conversion proves more difficult to understand, as it should given its complexity. Kuhn raises the issue of entrenchment by hypothesizing that younger scientists are more likely to flee a crisis-ridden paradigm. He implies a sort of intellectual rigidity, being stuck in a worldview, yet later extends this also to an economic entrenchment when one's livelihood is connected to certain intellectual commitments.[44] However these issues of entrenchment are not further capitulated as variables in Kuhn's explanation of conversion. He instead takes a pragmatic approach rooted in a paradigm's problem solving ability; a new paradigm will replace an old one if it can better solve problems in the old. Kuhn founds this approach in a crucial distinction about how theories are tested, separating him from those philosophers of science before him. He argues, quite controversially, that theories are not tested against nature itself but rather tested against other theories for "the allegiance of the scientific community."[45]This testing, Kuhn argues, comes in the form of crucial experiments which distinguish one paradigm from

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[43] Id., 144.
[44] Id., 169.
[45] Id., 145.

another.[46] Once scientists conduct such experiments they are able to juxtapose the problem-solving ability of the paradigms. Kuhn outlines the process of conversion in the last pages of SSR, first noting that scientists will generally not accept a new paradigm if it reopens old problems previously answered.[47] Instead, nature will undermine the old paradigm. This appears to conflict with Kuhn's argument that paradigms are tested against each other yet Kuhn contends that nature will produce a crisis in the old paradigm at which point paradigm testing occurs. Furthermore, failed testing against nature threatens professional security, the scientists themselves respond to their own economic interests and thereby make them more willing to leave the paradigm – they become less entrenched. Once these primary conditions are met Kuhn outlines two specific conditions for scientists to change their minds which are fairly straightforward. The new paradigm must solve novel problems that the old paradigm cannot and still must be able to solve most of the old problems.[48] By Kuhn's standards he sets up a notion of scientific advancement or what he doesn't shy away from calling "progress," specifically stating "the result of solving those problems must inevitably be progress."[49] He essentially pitches scientific advancement as a net gain in weighted problem solving abilities. Of course Kuhn again means strictly scientific problems, yet later we will see that it is difficult to separate scientific problems from technological and economic ones. One may even argue that Kuhn's mechanism is even more suited for economic revolutions. Take, for instance, the great agricultural revolution and emergence of animal husbandry. While living close quarters with animals spread disease and lowered the standard of living, it also solved the problem of finding

[46] Id., 153.
[47] Id., 169.
[48] Id.
[49] Id., 166.

food.[50] Many other societies resisted the revolution and now, after 10000 years, these societies are nearly extinct. The net gain advantage over time eventually converted nearly the entire world's generation of food.

From this stance it is easy to see how such a theory of scientific advancement could lead to a discussion of evolutionary scientific change. Kuhn's conception of paradigm shifts and conversion hints at an evolutionary character with his description of a revolution occurring through an "increasing shift in the distribution of professional allegiances."[51] In his closing pages Kuhn acknowledges that the process he has described is one of "evolution from primitive beginnings."[52] He uses this metaphor of evolution to consider science as objective truth comparing pre-Darwinian teleological evolution to those questing for absolute truth. Kuhn himself actively endorses a view of non-teleological scientific evolution, lacking the path of greater and greater approximations of scientific truth, calling it a "unidirectional and irreversible process."[53] Furthermore, while acknowledging that the evolutionary analogy could "be pushed too far," Kuhn argues that it is appropriate for describing scientific change. Scientific ideas evolve by retaining problem solving ability and adding new solutions to new problems. It is this idea where Kuhn and Popper find more common ground than has generally been acknowledged and also where the issue of teleological evolution becomes of central importance because of its metaphorical significance.

5. Survival of the Wit: Karl Popper and Evolutionary Epistemology

Kuhn's SSR is largely a response to Popper's *The Logic of Scientific Discovery*, and likewise Popper's work was largely a response to the logical positivists at the beginning of the

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[50] See Jared Diamond's argument in *Guns, Germs, and Steel* (New York: W.W. Norton, 1997).
[51] Kuhn, 158.
[52] Id., 171.
[53] Id., 206.

20th century. *The Logic of Scientific Discoveries* focuses on the problem of induction and how falsification of theories provides an answer as to how science generates knowledge. Originally printed in German in the 1930's, it said little about any generational or evolutionary aspects of science nor did Popper cite Planck's Principle. Instead, Popper's ideas relevant for our discussion here emerged from an exchange he had with Donald Campbell in the 1970s about the process outlined in *Logic of Scientific Discoveries* and his other works. I will not discuss the analogous evolutionary mechanisms in this work simply because so many of the concepts were developed in retrospect. Instead, all one really need know is the core premise in Popper's philosophy of science, falsifiability; and that knowledge grows through a process of ongoing conjectures and refutations. Theories that are tested and falsified are discarded and those that pass a testing will remain and be subjected to further scrutiny. In this sense theories that have not been refuted may be seen as surviving while those falsified go extinct. Campbell recognizes this analogy and uses it to establish a "natural selection epistemology," or the now widely-known "evolutionary epistemology."

The term "evolutionary epistemology" can be traced to Campbell's 1970 paper entitled as such in which he credits Karl Popper as the "modern founder and leading advocate" of such a philosophy. However, it should also be noted that this attribution to Popper may be more flattery than sincerity as Campbell also thanks 42 other scholars for their contributions in his first note, including Thomas Kuhn.[54] Indeed this illustrates the existence of some sort of inherent concept of evolutionary knowledge in varied forms and often with broader connotations of evolution. Since Campbell's paper, evolutionary epistemology has been linked more closely with the ideas of Konrad Lorenz and has split into two disciplines of philosophy and sociobiology. Campbell's

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[54] Donald T. Campbell, "Evolutionary Epistemology," in *The Philosophy of Karl Popper,* ed. Paul Arthur Schilpp (La Salle, IL: Open Court, 1974), 1:413n.

original work unites these two approaches in his definition of evolutionary epistemology stating that such an epistemology must be "compatible with man's status as a product of biological and social evolution."[55] He argues that as humans are a product of evolution, we have, over time, evolved mechanisms for knowing both biologically and socially. Campbell takes social evolution quite literally regarding the shifting characteristics of biological populations yet he also uses evolution as a metaphor. This comes off as somewhat troubling and may explain the later split between natural selection epistemology and naturalized epistemology. Campbell explains Popper's contribution as providing an analog to biological evolution noting Popper's "succession of theories in science as a similar selection elimination process."[56] He contends Popper's cognizant recognition of such evolutionary characteristics by noting that Popper employed rather evolutionary language in his own descriptions in *The Logic of Scientific Discoveries* where Popper referred to only the fittest ideas surviving.[57] However, it is one thing to make an analogy and quite another to actually apply the analogy. There is a substantial case to be made that *The Logic of Scientific Discoveries* and that earlier Popper had no intention of any evolutionary scheme.[58] Nonetheless it seems clear that later, Popper himself reformulated his own theories into those resembling evolutionary epistemology, going so far as to compare genetic mutations to "trial and error gambits."[59] Popper, like Kuhn, had come to embrace an evolutionary theory of scientific change, albeit a slightly different one.

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[55] Id., 413.
[56] Id., 415.
[57] Karl Popper, *The Logic of Scientific Discovery* (London: Hutchinson and Co., 1959), 42.
[58] Popper's references in LSD to evolution are figurative at best, and even his later references from *Of Clouds and Clocks* and *Objective Knowledge* seems more digressions than advocation.
[59] Karl Popper, *Objective Knowledge* (Oxford: Clarendon Press, 1972), 242.

Campbell also notes that perhaps Popper was less interested in the activity of science than the "logic of knowing."[60] Indeed, Popper spends just as much, if not more, time responding to Kant as he does to positivism in the *Logic of Scientific Discoveries*, perhaps following the standard philosophical tradition of conjectures and refutations. This may appear to distinguish his approach completely from Kuhn who strictly historicizes and socializes science as a human activity rather than a knowledge process yet we find that in the end they will share quite a bit in common despite such opposite approaches. In fact, part of what Campbell is doing is reconciling Popper and Kuhn.[61] While he only slightly hints at the similarities in this paper, he published a paper a year earlier arguing for their compatibility.

Before discussing Popper's response and the nuances of his evolutionary theory, it might be helpful to place Popper's theory in Campbell's own context at the time. Campbell was very much concerned about social evolution and argued that the next step would be grand social experiments. This conjecture stemmed from his belief that evolutionary processes permeated all levels of society and culture, not merely biological, but all adhering to the evolutionary process of blind variation – selective retention, another phrase coined by Campbell. It is in this sense that Campbell both uses evolution metaphorically and literally; he redefines evolutionary change by proposing "blind variation – selective retention" as the universal mechanism driving evolution. In Campbell's 1970 introduction of evolutionary epistemology he also outlines a total of 10 nested levels of evolutionary knowledge developments, the last three of these being language, cultural cumulation, and science. While this path of knowledge growth is not necessarily teleological Campbell does make the hierarchy appear inevitable. Evolution for

[60] Campbell, 419.
[61] See Donald Campbell's 1969 essay, "The Experimental Society," in *The Experimenting Society: Essays in Honor of Donald T. Campbell*, ed. William Dunn (New Brunswick: Transaction, 1998).

Campbell is about problem solving and science rests at the pinnacle of this nested hierarchy. Others writing in the field of evolutionary epistemology have expressed similar sentiments; for example the epistemologist Manevar writes, "science is a social expression of intelligence in dealing with the world."[62] However, this position seems difficult to reconcile with those held by historians of the scientific revolution who argue the emergence of the activity of science was due to a variety of factors which were not at all inevitable. I imagine further dialogue resulting in which evolutionary epistemologists would either argue that science is merely the path evolution chose and that such a nested hierarchy is not meant to be abstracted at all but provide concepts to understanding the evolution of problem-solving abilities, or that given language and cultural accumulation, science is inevitable. In the latter evolution need not be teleological, but some evolutionary developments that lead to problem-solving abilities will create a lock-in that leads to others. In the end, this scheme of hierarchical problem solving with biological and social evolution bears a resemblance to the scheme put forth by Kuhn where theories are chosen based on a net benefit in problem solving ability.

Evolutionary epistemology in general, however, does not shy away from the teleological implications of such a survival of ideas. As another author, Rescher, explains, "However implausible a rationally teleological approach may be in strictly biological evolution, it is evidently and unproblematically tenable in methodological evolution in matter pertaining to the modus operandi of intelligent and rational beings."[63] Rescher further highlights the differences amongst evolutionists in whether to consider variation as blind (random) or purposeful, and whether selection is natural or rational. His analysis in centered, like Campbell's, on this

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[62] Gonzalo Munevar, "Science as Part of Nature," *Issues in Evolutionary Epistemology,* ed. Kal Hahlweg and C. Hooker (Albany: State University of New York, 1989), 476.
[63] Nicholas Rescher, *A Useful Inheritance* (Savage, MD: Rowman & Littlefield Publishers, 1990), 12.

appropriated variation-selection mechanism. In Popper's own theory of evolutionary scientific change, he displays a somewhat ambiguous attitude to these issues.

It is not often that one author responds with praise to another who has given their work a critical analysis, yet Popper's response to Campbell sounds as if he has found his long lost twin.[64] This might be, as Popper writes, because Popper himself was developing similar ideas at the time of Campbell's essay.[65] The response that follows from Popper therefore becomes much more a commentary on the similarities between their approaches. Popper's three worlds, the objective world (world 1), the sense world (world 2), and the articulated world (world 3) slightly mirror Campbell's ten levels of evolution, at least in differentiating knowledge. Popper delves further to give an evolutionary backing to his worlds and building on Campbell argues that given Darwinian theory, people are active and curious explorers. He writes, "we are active explorers (explorers by trial and error) rather than passive recipients of information impressed upon us from outside (Lamarckism, inductivism)."[66] This is not the first nor last time Popper specifically aligns his philosophy with Darwinian or neo-Darwinian evolution, but here he attempts to state that his philosophy is both inherently true and innately human. This elaboration of course seems a step too far; nature's trial and error system is quite different than any individual's. However, Popper continues later to argue for an "innate drive to find out, to understand, to correlate," and contends a psychological basis for Kant's notion of a priori knowledge.[67] Popper, Campbell and others have argued that the reason people think in terms of causality is dictated by our psychology as developed through evolution. Popper sees this as further proof, or corroboration,

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[64] Popper even notes in an earlier response that most of the papers attempt a refutation of his ideas, Karl Popper, "Karl Popper, Replies to my Critics," in *The Philosophy of Karl Popper*, ed. Paul Arthur Schilpp (La Salle, IL: Open Court, 1974), 2:1053.
[65] Id., 1059.
[66] Id., 1060.
[67] Id., 1062-1064.

of nature expressing the latest development in intelligence. Popper's next point is his utmost enthusiasm for the use of the term blindness in the trial and error method. Campbell uses this term instead of the more common biologically-connotated "random" variation simply because random does not appropriately fit scientific testing whereas blindness connotes the knowledge that we are still searching for, or the unknown. Popper also uses blindness in his argument against what he sees as both Lamarckian and inductivist, that we simply absorb knowledge. A blind man does not learn from absorption, Popper argues, but by actively testing and searching.

Thus far we have seen Popper's original conception of falsifiability from *The Logic of Scientific Discoveries*, Campbell's first codification of evolutionary epistemology, more mature evolutionary epistemology discussions, and finally Popper's own conception of evolutionary epistemology. But what do these offer for the discussion of generational change, something Popper or Campbell do not explicitly mention. One simple interpretation, or answer to this question, is that Popper does address it implicitly by ignoring its influence on the selection criteria. In other words, one can see Popper's evolutionary epistemology as assuming a total malleability of belief. Indeed the image of humans painted by Popper is one of constantly searching and striving towards the unknown, not those that find themselves content with the known. If scientists and others all agreed on some sort of objective criteria to determine which theories are falsified, and they were bound to such an agreement, then Popper could present a coherent analysis of generational change. This distinction further highlights the juxtaposition found between Planck's Principle and Popper's Principle (falsifiability); one assumes full conversions while the other, in an extreme form, assumes no conversions. When applied in the context of sociobiology or evolutionary epistemology these contrasting views are boiled down to simply ones on human nature – stubbornness versus curiosity, rigidity versus malleability of belief.

Transfer of knowledge is also neglected which seems somewhat odd given Popper's heavy and nuanced discussion of the blindness of variation, one may wonder why he does not give the same amount of scrutiny to the retention aspect. However, theories that survive falsifiability do not just strictly survive in Popperian evolution yet also emerge changed and refined, or mutated.[68] So the Popperian blindness is at least for a time lifted to allow for such modifications. Popper once stated that "knowledge starts from problems and ends with problems," and that theories link and define their path.[69] The surviving theories also evolve this way as they are built exclusively around problem areas whose testing exposes new problem areas. This form of evolution, unlike the simple falsification of ideas, puts a much greater emphasis on the passage of time. Framing scientific change in terms of problem areas or research questions places it more as a grounded time-consuming process than an abstraction of a blind man searching for a hat or an amoeba in its own trial and error quest.[70] Unfortunately this is as close as Popper gets to any historical time-dependent process; his evolution relies on conjectures and refutations for progression, whereas biological evolution relies on the passage of time. Furthermore there can be no closure in Popper's science; the process of discovery is ongoing and controversies are resolved through the falsification of certain theories. The only way controversies arise is if two competing hypotheses are proposed in the blind search for a solution to the problem.

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[68] Popper also compares theories to mutations themselves, *Objective Knowledge*, 242.
[69] Popper, *Objective Knowledge*, 144.
[70] Popper's actual analogy was "a blind man who searches in a dark room for a black hat which is – perhaps – not there," (Popper, "Replies to My Critics," 1061) which seems completely redundant because as long as the man is blind it shouldn't matter whether the room is dark or the hat black.

Rescher also notes that any scientific progress made according to Popper's scheme would be "inexplicable" and "miraculous."[71] He takes the sociobiology position in evolutionary epistemology and stresses the difference between blindness in biological evolution versus blindness in cultural evolution, arguing against any application of the latter.[72] Since the original synthesis Campbell proposed, which he indebted to Popper's falsification mechanism, he too has shifted away from Popperian evolutionary epistemology and later referred to his theory as "general selection theory" or selection theory epistemology.[73] This may be appropriately reformulated in a universal selection theory as Campbell's "blind-variation-selective-retention" process permeates across all levels of evolutionary development, including language and science. Yet Campbell's view of the epigenetic origins of human psychology and Popper's concurrence on this point also adds something to a generational discussion. Giving human psychology a basis in evolution is nothing new, nor is attributing human nature to some quasi-teleological mechanism of knowledge growth in nature.[74] Still, such an approach implies a differentiated nature over the lifetime of an organism and thus changes with age become key aspects for survival. Evolutionary epistemologists will even refer to such changes as an evolution of cognitive processes in humans, and studies have attempted to show a link between creativity and age.[75]

From this analysis we see Popperian evolutionary epistemology in the light of a more grounded vision of time-dependent, generational scientific change. Popper wholly appropriated

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[71] Rescher, 15-32.
[72] Id., 20.
[73] Gary Cziko, "Universal Selection Theory and the Complementarity of Different Types of Blind Variation and Selective Retention," in *Selection Theory and Social Construction* ed. Cecilia Heyes and David Hull (Albany: State University of New York, 2001), 17.
[74] I say quasi because puzzle-solving is seen as the driving mechanism rather than pure *natural* selection, in this sense evolution will yield more and more complex puzzle-solving abilities.
[75] Cziko, 25-27.

a Darwinistic evolutionary metaphor for theories while Campbell took evolutionary mechanisms and attempted to apply them to all possible biological extensions such as psychology and sociology. Campbell, a psychologist by training, saw science as a strictly human activity and therefore saw it as subject to the evolutionary laws in biology. As Campbell rightly notes however, Popper is much more concerned about the logic of knowing, than to the extent that evolutionary processes are deterministic of human activity. Because of these wildly different approaches, there presently exists an ambiguity about what evolutionary epistemology entails and exactly how far a Darwinian evolutionary metaphor may be appropriated before it becomes pure metaphysics.[76]

Popper's analysis of scientific change is in some respects remarkably different from Kuhn's. Simply the historical and sociological considerations of Kuhn versus the strictly epistemological considerations of Popper provide enough evidence for this. Kuhn's evolution is about the transfer ideas through education and scientific closure whereas Popper's is more about the persistence and survival of ideas. But the authors do have some things in common besides the broad application of an evolutionary metaphor. The last pages of SSR, where Kuhn discusses evolution specifically, provide a departure from the rest of the book and take Kuhn into the field of evolutionary epistemology. Kuhn's own conception of the survival of ideas appears to mirror that of Campbell and Popper in its general sentiment and in "The Road since Structure" Kuhn further outlined his evolutionary scheme. Like Popper's evolutionary epistemology, Kuhn's has also been thoroughly criticized. Barbara Renzi (2008) analyzes Kuhn's evolutionary

[76] See, *The Return of Science: Evolutionary Ideas and History* for several articles questioning the extent evolutionary metaphors have been used and Kuhn's own evolutionary epistemology.

appropriation and clearly shows that when specific biological analogues are made, the metaphor begins to break down.[77] But perhaps this is just in the general nature of metaphors.

6. Feyerabend's Free Market of Ideas

Adding Kuhn's SSR and Popper's *The Logic of Scientific Discovery*, Feyerabend's *Against Method* rounds out this triad of great works in the history and philosophy of science. Feyerabend's work is the most contemporary and therefore serves as a response to both Popper and Kuhn's theories as well as their developments in the following decades. However, Popper's later evolutionary epistemology developed too late for his work. More specifically though, Feyerabend is responding to Imre Lakatos, a fellow philosopher of science, who, to describe it simply, combined the theories of Popper and Kuhn into the conception of research programmes which are essentially paradigms with different layers of testability. So in the name of simplicity, Feyerabend can be seen as responding to both Popper and Kuhn in his response to Lakatos.

Feyerabend's conception of science does not have a structure like Kuhn's or a method like Popper's; it has no structure at all. His one-sentence introduction does it more justice than any other synopsis: "Science is an essentially anarchistic enterprise: theoretical anarchism is more humanitarian and more likely to encourage progress than its law-and-order alternatives."[78] This synopsis alone gives us enough hints as to how a generational or evolutionary scheme for science would proceed, but we should question what Feyerabend means by progress. Luckily he provides just such an answer early on in *Against Method*:

> Incidentally, it should be pointed out that my frequent use of such words as progress, advance, improvement, etc., does not mean that I claim to possess

[77] See Barbara Renzi, "Kuhn's Evolutionary Epistemology and Its Being Undermined by Inadequate Biological Concepts," *Philosophy of Science* 76 (April 2009): 143-159.

[78] Feyerabend, 17.

> special knowledge about what is good and what is bad in the sciences and that I want to impose this knowledge upon my readers. *Everyone can read the terms in his own way* and in accordance with the tradition to which he belongs. Thus for an empiricist, 'progress' will mean transition to a theory that provides direct empirical tests for most of its basic assumptions…For others, 'progress' may mean unification and harmony, perhaps even at the expense of empirical adequacy…*And my thesis is that anarchism helps to achieve progress in any one of the senses one cares to choose*. Even a law-and-order science will succeed only if anarchistic moves are occasionally allowed to take place.[79]

Feyerabend's explanation here is important for at least two reasons. First, it nearly makes part of his own thesis a truism, not that science is anarchistic but that anarchism brings about the best chances for progress. If progress is defined in such a way as to accompany many different subjective views then it essentially defines such progress as anarchistic. In the same way an empiricist society working under their own law-and-order scientific regime would say that their system maximizes their own progress. Second, and more importantly, one cannot speak of any such universal progress given these equally valid meanings of progress. The formulation of theories has no purposeful direction other than to fill the niche of its own habitat. The evolutionary character should be clear. Feyerabend's progress is truly blind, his selection natural, and his evolution non-teleological; scientific progress under this model may only be articulated in retrospect. His anarchism may easily be equated with the unguided natural selection of Darwinian evolution. Furthermore, Feyerabend's last sentence seems to imply that anarchism may be the catalyst for mutations that allow for evolutionary progress. This type of

[79] Id., 27.

evolutionary progress depends on a mutation leading to some beneficial reproductive gain for a species within its own context and so too for Feyerabend's progress. For each tradition, progress will be seen within the context of the theory.

From his introductory statement it should also be clear what Feyerabend's goal is with his theory, or non-theory. A survivor of the authoritarian regimes in World War II, he believes that the more theories proposed and the more ways of looking at things the better and the more competition there is between ideas the more we have to gain. Therefore, through a competition mechanism there is a clear economic correlation with Feyerabend's ideology. The more methodologies and mindsets in the market competing against one another, the greater chance there would be of scientific advancement. More specifically, the free market and evolutionary metaphors are closely related, again through the mechanism of competition, yet it seems more appropriate to apply the free-market to Feyerabend's argument, if only because it's connotation more closely resembles his political-economic label of an anarchistic theory of knowledge. So if we take the metaphor of the free-market what does it look like? Feyerabend again provides an elegant answer:

> Knowledge so conceived is not a series of self-consistent theories that converges towards an ideal view; it is not a gradual approach to the truth. It is rather an ever increasing *ocean of mutually incompatible (and perhaps even incommensurable) alternatives,* each single theory, each fairy tale, each myth that is part of the collection forcing the others into greater articulation and all of them contributing, via this process of competition, to the development of our consciousness.[80]

[80] Id., 30.

It should immediately be noted that Feyerabend's goal is not concerned as much with epistemology as it is with understanding. It is not so much how we know but that we know. Theories can only gain traction by appealing to a prospective audience and people will choose from theories based on their own desires, upbringing, or rationality. Theories, like firms, compete for consumers and those that maximize utility will be successful. One could easily continue with the economic analogy. When theories force "others into greater articulation" it means exerting a competitive pressure on those theories to force their refinement in order to survive, the same way that firms force each other to improve their efficiency and lower their marginal costs. Theories, tales, myths, and ideas may act as complements and substitutes to each other and even specifically economic concepts like a Giffen good have analogues in a free-market of theories. For example, a Giffen good is one in which an increase in price also causes an increase in demand. Therefore such a theory could be described as negative theory or one that seeks to preserve a mystery rather than explain it. The recent Intelligence Design movement may be seen as a Giffen good type of theory, or perhaps even Feyerabend's own theory. These may mean the same thing as when one calls intelligent design a "negative" theory, as its primary purpose is to undermine another theory.

This economic analogy gives us a more general background to examine some of the more specific mechanisms Feyerabend hints at in *Against Method*. To begin, Feyerabend's thesis is partly borne out of criticisms in the structure of education, comparing it to brainwashing and highly criticizes a discipline-framed education.[81] Teaching science as the culmination and simplification of works in a particular field stifles the ability of the student to bring in outside influences or to be able to see a broader picture. Students are taught a "logic" of their discipline

[81] Id., 19.

and as such lose all individuality, instead being hampered by "laws, duties, or obligations."[82] However, Feyerabend does not attempt to provide an alternative to such a system other than to argue for a program of anarchy.

Feyerabend's education discussion further highlights his concern about people trying to demarcate science and what constitutes it. Those that propose a logic to science or insist on teaching a certain methodology could end up harming the pursuit. Feyerabend points to examples from the history of science to illustrate a diversity of beliefs and approaches which have yielded progress in the past. He therefore extends this to argue that if a certain methodology in the past worked then it should not be excluded from scientific work today, nor should any other approach. In this sense, he and Popper share a belief that all possible theories have an equal standing. While Popper's are tested and falsified, Feyerabend's emerge with a cultural, and often personal, relevance and resonance. He is also not concerned so much with scientists changing their minds as he sees this as a product of too rigid a scientific education. If the education is removed then scientists will ideally be open to as many ideas as possible. Therefore Feyerabend argues for some scientific ideal just as Kuhn and Popper had, even as he rails against such. Furthermore, Feyerabend's own argument "against method" is not to do away with method, yet to provide for the greatest diversity of methods.

Feyerabend does not reference Planck with the same directness as Kuhn, but he does make note of Planck's Principle in a fairly macabre way. In his contribution to *Criticism and the Growth of Knowledge*, Feyerabend comments on Kuhnian conversions, contending that "Killing the representatives of the *status quo* would be another way of breaking up a paradigm."[83] In his

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[82] Id., 20.
[83] Paul Feyerabend, "Consolations for the Specialist" in *Criticism and the Growth of Knowledge* ed. Imre Lakatos and Alan Musgrave (Cambridge: Cambridge University Press, 1970), 203.

note he draws the comparison to how religious or political change occurs. He acknowledges Planck's Principle yet somewhat sarcastically remarks that even though "the principle remains…murder is no longer the accepted method."[84] This reference is not the only place where Feyerabend contends that theoretical change comes from coercion within a community. In *Against Method* he notes that "Old style doctors, for example, must either be removed from medical practice, or they must be re-educated."[85] Again, as a brief aside, we see that age is an issue only so much as it correlates with adherence to older theories or modes of thinking – an old-style doctor need not necessarily be old. Feyerabend's version of Planck also appears to him as self-evident, but not the underlying principle of change, and this is perhaps best explained by Feyerabend's emphasis on individuality. His concern is with how individuals come to support or reject theories rather than how communities adopt a theory. Placing the individual at the center of analysis is not only an axiom in anarchistic theory, but also in economic theory. The individual consumer takes a prominent role in dictating both the demands of the economy as well as determining the validity of any theory.

Feyerabend also addresses Kuhn's contention that any new theory should leave the problem-solving of the old theory mostly intact. He labels this the consistency condition and his refutation of it again gives us a hint at his generational mechanisms. He argues that if this view of science is correct then the first theory that can adequately explain some phenomenon has a "right of priority" over later ones.[86] "It contributes to the preservation of the old and familiar not because of any inherent advantage in it – for example, not because it has a better foundation in observation than has the newly suggested alternative, or because it is more elegant – but because

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[84] Id., 203n.
[85] Feyerabend, 50.
[86] Id., 36.

it is old and familiar."[87] His statement serves as a philosophical distinction to account for anomalies that would arise if science obeyed a logic in which its theories were solely judged. This explanation rests however on the same basic principle of human nature invoked by Planck in his principle and countless others before and after him. Familiarity trumps rational choice; Planck's new generation does not choose their new scientific truth but becomes familiar with it. Feyerabend uses this fact of human nature to disprove the consistency condition as people would never have any incentive to switch to theories that solve the same puzzles as before.

Feyerabend points out the real world economic consequences of switching theories or championing a new theory, "textbooks must be rewritten, university curricula readjusted, experimental results reinterpreted."[88] On top of a certain psychological or intellectual rigidity that science confronts, it also bears the burden of economic rigidity in the form of transaction costs. He uses this economic notion literally to again argue against the consistency condition and using his logic we may reformulate this principle of transaction costs to state that any theory that mandates such costs must hold a problem-solving advantage over the status quo to outweigh such costs. A theory that already agrees with existing hypotheses would not warrant such a change according to Feyerabend. Kuhn posited something similar in that a new theory, while not necessarily needing to agree with all aspects of already accepted theories, does need to present an overall gain in problem solving ability. Feyerabend simply extends this to real world cost considerations as well.

Feyerabend's anarchism, while built off political notions of anarchism, only advocates an anarchistic scientific methodology. Thus the free market analogy seems most appropriate, especially when contrasted against a metaphor of capitalism or even laissez-faire economics.

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[87] Id.
[88] Id., 37.

Feyerabend's anarchism of ideas is not meant to promote total deregulation of science and belief systems where certain ideas may naturally come to dominate the intellectual landscape. A quick clarification of such economic analogies will help to illuminate. Laissez-faire economics, capitalism, and the free-market are conflated with each other, often under the dogma of free-market capitalism and popular amongst libertarians following Austrian economics. By strict economic definitions a free market is clearly differentiated from capitalism, which is defined as a system where the means of production are privately owned. Instead, the free market refers to an open market without regulation, which places an emphasis on efficiency as its guiding principle. However, an open market is one in which competitors can enter the market freely and in uncompetitive free markets this may not be the case. A free market in a strictly economic context is an oxymoron, it essentially is an argument for anarchism which would immediately degenerate into something much less than a free market. A free market in the prolific libertarian Robert Nozick's minimalist state (the step above anarchy) would lead to a free and open market just as surely as anarchy would quickly lead to a free and open society. Instead the term free market is much more generally articulated as a relative term in a world of mixed economies to denote a competitive and open market control without excessive intervention. In the most practical sense then, a free market is often enforced through government regulation which ensures market entry and prevents any one firm from gaining too much market power. It is this scheme which Feyerabend wishes for the maximum proliferation of ideas. His notion of chauvinistic science acts as a monopoly in epistemology by blocking the entry, and nullifying the validity, of other methodologies. He even specifically argues for intervention to reduce rigidity of thought: "It often happens that parts of science become hardened and intolerant so that proliferation must be enforced from the outside, and by political means."[89] The diversity of theories does not in itself constitute scientific progress, but does expedite the process. We do not know the content of future scientific theories and therefore should not restrict any inspiration for such content. Just like in the economy, education needs regulation and protection, a free market of ideas does not arise out of anarchism but out of the structure of science itself which allows for a regulation of ideas. In true anarchism things have a distinct possibility of degenerating into duopolistic and monopolistic systems.

We may sum up Feyerabend's view then thusly. The free-market metaphor seems the most appropriate in its description of Feyerabend's scientific progress as well as his own ideal scientific structure. Science succumbs to the resistance characterized by Planck because of the rigidity in science education which narrowly defines valid methodologies and attempts to chip away outside influences. Feyerabend instead suggests that each new generation develop as individuals in hopes that such diversity will yield scientific progress. Ironically, for this to occur, methodological anarchism needs some sort of regulation to prevent any scientific chauvinism, or domination of the epistemological market. These checks are necessary if a maximum rate of scientific progress is desired.

7. Self-Organizing Principles in the Philosophy of Science and Beyond

Feyerabend's conception of science seeks to restructure the endeavor to allow for many competing viewpoints. Science as it really exists needs to be changed to reflect the diversity found in the history of science. I have used the free market analogy above because it more clearly reflects Feyerabend's own notion of efficiency in scientific progress as well as his own appeal to politico-economic concerns. As has been hinted at earlier, the evolutionary analogy

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[89] Id., 51.

may also have been appropriated to describe competition between methodologies and theories. Feyerabend's "ever increasing ocean" of theories does not seem to imply extinction, yet evolution occurs through greater articulation of theories, implying that less articulated theories will be discarded. Indeed, one could go through Feyerabend and find many instances of evolutionary and free-market analogies.

For Kuhn, Popper, and Feyerabend competition is central to scientific change albeit in different forms. Science in both Kuhn and Feyerabend progresses with theories being tested against each other in direct competition. Popper takes a slightly different route in that each theory is tested against nature to determine whether it survives and this gives Popper's a more direct evolutionary comparison. It is not hard to recognize that ideas come and go or that they compete with one another, to spend time defending this would be as fruitful as arguing the opposite. Yet this simple self-evident structure manifests itself differently in each of these philosophies of science and so we find both the key similarities as well as a unique twist in the concept in the works of Kuhn, Popper, and Feyerabend. This is best illustrated for purposes of this paper by the close relationship between economic theory and Darwinism.

Charles Darwin, in his theory of natural selection, took direct inspiration from another author, English political economist Thomas Malthus. Malthus's work in fact influenced several other prominent Darwinists, most notably Alfred Russell Wallace and Herbert Spencer. These men looked to Malthus's analysis of population and the competition for resources which he predicted would lead to a catastrophe if population was allowed to grow unchecked. He presented a rather grim picture of a human population competing for resources, in this case a limited food supply. This formulation of competition formed the background for natural selection, as Darwin explains in his *Origins*, "This is the doctrine of Malthus, applied with manifold force to the animal and vegetable kingdoms, for in this case there can be no artificial increase of food, and no prudential restraint from marriage."[90] Fortunately, as Darwin alludes, a Malthusian crisis did not occur in England as farm productivity increased and a demographic shift slowed population growth. Darwin's theory, on the other hand, did fundamentally change biological science, and fairly quickly as Hull et al pointed out in their Planck's Principle study. Economic and evolutionary metaphors are therefore at least marginally linked through their origin.

The economic and evolutionary back and forth interplay of ideas and mechanisms did not end there. Both premises are based on an allocation of resources and prescribe "efficiency" or "fitness" as the key factor. In this sense economic efficiency does not refer to technical efficiency in terms of production, but rather simply market forces and those that closely mirror the forces in natural selection. Feyerabend's argument against method relies on progress through diversity – any scientific research program must be allowed to make anarchistic moves. Similarly, evolutionary fitness thrives on diversity and variation. There is one major difference between the two however; one only pertains to humans. Therefore, while Darwinian evolution relies on external causality for progress, Feyerabend's notion of progress is not purely externally causal as no human activity could possibly ever be. Nonetheless, in classical economic theory, the invisible hand serves as the external organizing agent. Even Darwin, after reading Malthus had rejected the notion that extinctions have geographic or external causes, but instead that a species simply had its own internal lifetime.[91]

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[90] Darwin, 63.
[91] M.J.S. Hodge, "Capitalist Contexts for Darwinian Theory: Land, Finance, Industry, and Empire," *Journal of the History of Biology* 42 (2009), 408.

Despite, the similarity and close relationship between economic and evolutionary mechanisms, biologists Walsh, Lewens, and Ariew caution against taking evolutionary forces too literally. They argue that dynamical theories of evolution that focus on selective pressures give an incorrect picture of what evolution really comprises. Instead, evolution should be described statistically through changes in population.[92] Economic theory on the other hand does not make the same distinction, pressures on the market are corroborated by statistical analysis. This mutualism may arise from economics ability to create its own nature and perform ongoing experiments. Economics, both as a discipline and as a business strategy dominates the global markets and is enforced through governmental functions such as contract enforcement. Firms are not only expected to act rationally but operate in an economically consistent manner. By all actors playing by a basic set of economic rules, economists can generate certain results within the economy. In a way, as a community, economists have created theistic economic evolution by creating the invisible hand.

Other authors have also noted the similarities between market-clearing forces embodied in Adam Smith's invisible hand, or at least his notion of it, and the pressures exerted through natural selection. Toni Carey has proposed that both these concepts as well as some of their predecessor concepts arise from a parent principle that is neither strictly economic nor biological in character. Instead she describes this principle as one where "collective order and well-being can emerge parsimoniously from the dispersed (inter)action of individuals."[93] This type of natural allocation might serve as a background for Feyerabend and Popper's philosophy of science, and slightly less so for Kuhn. This may simply arise because Feyerabend and Popper

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[92] Walsh et al, "The Trials of Life: Natural Selection and Random Drift," *Philosophy of Science* 69 (Sept. 2002), 453.
[93] Toni Carey, "The Invisible Hand of Natural Selection and Vice Versa," *Biology and Philosophy* 13 (1998), 427.

are much more concerned with the philosophy of science in their works rather than the more sociologically-framed practice of science. Both Feyerabend and Popper, in *Against Method* and *Logic of Scientific Discovery,* place a central concern on how science is described within the philosophy of science. While Kuhn shares similar concerns he focuses more on what drives science in his SSR, especially in the context of generational change. Feyerabend, while departing from Popper in his approach, and drawing from the same pool of history that Kuhn uses, concludes *Against Method* with a prescription for the philosophy of science. All his arguments against prescribing a particular method to science, lead to a prescription of how science should be taught, creating a happy coincidence of both scientific and humanitarian progress for Feyerabend.

Feyerabend's prescription follows this parent principle defined by Carey and therefore, his ideal conception of science follows an evolutionary or invisible hand principle similar to Popper's evolutionary epistemology. Delineating this principle in Feyerabend's work is particularly illuminating because of how he frames his work politically. Carey contrasts the parent principle of collective order embodied in natural selection and the invisible hand with the "conspiracy theory of society," or one where order is created strictly in a top-down matter.[94] This simple juxtaposition allows a clear view of Feyerabend's concern with order and highlighted by his own statement that "even a law-and-order science will succeed only if anarchistic moves are occasionally allowed to take place."[95] Feyerabend deplores the controlling hand of chauvinistic science and the top-down order it inflicts and so instead trumpets the individualistic development of scientists as a way of founding scientific enterprise from the bottom-up, from the individual. This description of Feyerabend's use of such a "parent

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[94] Carey, 429.
[95] Feyerabend, 27.

principle" seems fairly foreign to Popper's evolutionary epistemology as the former focuses on the individual scientist as the base and the latter makes an individual theory or idea the central bottom unit. Popper, in *LSD* and his works on EE, shows little concern with political imposition of control, power, or order yet as Carey notes, "Popper goes even further, taking the invisible hand beyond methodology and into content" when describing the main task of the theoretical social sciences in *Conjectures and Refutations*.[96] In fact, Popper's observation about sociology highlights another aspect of such a parent principle – the notion of emergence.

Social emergence is still a fairly controversial notion as Keith Sawyer has outlined in his recent 2005 work, *Social Emergence: Societies as Complex Systems* while strongly defending the validity of such a concept.[97] Both Feyerabend and Popper's theories essentially propose a theory of emergence, where the features of a system cannot accurately be described solely from the aggregation of the individual actors. Feyerabend stresses the uncertainty involved in knowledge generation and that progress in any subjective sense is expedited by increasing exposure to other methodologies; progress emerges from this "ever increasing ocean." In Popper's evolutionary epistemology, only a methodology built on falsification is supported, yet from this principle and the infinite number of falsifiable theories, scientific progress also emerges. However, there is one major difference between Feyerabend and Popper in this area: it is difficult to apply social emergence to Popper. Feyerabend's notion of science relies on people choosing between theories, often for non-rational reasons. Popper instead minimizes any psychological or social influence; we still have a choice in theories, but the selection criteria should be objective. Using his evolutionary metaphor, Popper explains, "We choose the theory which best holds its own in

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[96] Carey, 429.

[97] See Keith Sawyer, *Social Emergence: Societies as Complex Systems,* (Cambridge: Cambridge University Press, 2005).

competition with other theories; the one which, by natural selection, proves itself the fittest to survive."[98] Here we might say that Feyerabend's "anything goes" selection mechanism is actually more natural than Popper's. He instead really proposes a rational selection mechanism, one which may have lead him down the road of Lamarckism later. Popper's rational selection mechanism also resembles the soft teleology present in Campbell's puzzle-solving hierarchy and Kuhn's brief evolutionary epistemology venture in SSR. It is also this neglect, or this focus on rational selection that causes Popper to ignore Planck's Principle.

There is no doubt that evolutionary, economic, sociological theories of collective order are intertwined both historically and conceptually. Toni Carey sees her own argument for a parent principle as merely taking note of other works, citing, Popper, Campbell, Hull, and the libertarian lawyer Robert Nozick among others, and merely considering her argument that natural selection and the invisible hand should be counted as sibling concepts of a larger family rather than one creating the other.[99] Another author, Christian Cordes is also concerned with the appropriation of the collective order metaphor, yet for simplicity dispends with describing the appropriate conceptual relationship between the concepts. Instead he takes Darwinism as the base and seeks to distinguish between a "Universal Darwinism" and a "continuity hypothesis." While he proposes this distinction specifically in the context of economics, we may find his analysis particularly useful to discuss Popper's evolutionary epistemology and what has been called Kuhn's evolutionary epistemology.

Cordes, building on earlier authors, defines Universal Darwinism to be "a core set of Darwinian principles that, along with auxiliary explanations specific to each scientific domain, is

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[98] Popper, *LSD*, 91.
[99] In her introduction Carey states, "In this study, I build on what, since circa 1950, has become a distinguished body of scholarship…" (427-428).

considered applicable to a wide range of phenomena."[100] The term Universal Darwinism itself comes from Richard Dawkins, one of today's foremost and unapologetic proponents of Neo-Darwinian evolution. It may be no surprise then that Universal Darwinism in its extreme form seeks to apply the specific principles of Darwinism to cultural evolution and any other system that changes over time in a non-metaphorical way. The continuity hypothesis, on the other hand, does not see the same evolutionary mechanisms involved in cultural and biological evolution yet does see a continuity between both. As Cordes formulates it, "There is an ontological continuity between biological and cultural evolution, despite the fact that mechanisms and regularities differ between these domains. Culture evolves following its own regularities on the foundations laid before by natural selection in the form of innate human dispositions."[101] Because of his economic focus, Cordes ignores evolutionary epistemology in his discussion. If he had not he may have also included the analogous issues present in Popper's evolutionary epistemology and within disciplinary evolutionary epistemology in general.

As discussed briefly earlier, evolutionary epistemology has a dual meaning. In a philosophical context it means studying how knowledge evolves through some sort of natural selection, such as Popper's notion of falsification. Theories, ideas and beliefs survive or die letting knowledge evolve. In a biological context, evolutionary epistemology is much better represented by Campbell's "blind variation-selective retention" approach and his hierarchy of problem-solving. Campbell's approach clearly represents a form of Universal Darwinism with his evolutionary mechanisms permeating all levels of his hierarchy. Popper's falsification may be seen instead as part of the continuity hypothesis where knowledge maintains an evolutionary

[100] Christian Cordes, "Darwinism in Economics: From Analogy to Continuity," *Journal of Evolutionary Economics* 16 (2006), 530.
[101] Id., 531.

character metaphorically yet has some cognitive backing and an ontological continuity. This backing arises from Popper's arguments about how knowledge is generated through such an evolution – the falsifying process is an innate and rational one. However, Popper takes the continuity hypothesis one step further.

Another author, Bence Nanay, in an article published this summer, points out Popper's transition between interpretations of his evolutionary epistemology. Nanay describes Poppers transition from using "the Darwinian process as a model for understanding the growth of scientific knowledge" to using "his new insights about the growth of scientific knowledge to figure out the real nature of Darwinian selection."[102] Campbell's mechanism of "blind variation-selective retention" is an example of Popper's later interpretation. Indeed, this distinction helps to clear up the differences in meaning of evolutionary epistemology to either describe the survival of ideas or a naturalized epistemology founded in biological Darwinism. That these ideas of Popper and evolutionary epistemologists correlate so well with the hypotheses Cordes highlights in the economic debate perhaps says something profound about an inherent problem in attempting to appropriate the natural selection metaphor. A parent principle implies Universal Something-Akin-To-Darwinism yet the continuity hypothesis, codified in Campbell's hierarchy of problem-solving, implies nothing less than a soft teleology. As Nanay argues, Popper's later view also explains Popper's brief foray into Lamarckism. When rewriting his own Universal Darwinism, Popper realized that his analogy of mutations in knowledge could not be completely random.[103] Furthermore, he struggled with the idea of blind variation in biological evolution, questioning how Darwinian evolution could achieve seemingly goal-directed outcomes, such as

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[102] Bence Nanay, "Popper's Darwinian Analogy," *Perspectives on Science* 19 no. 3 (2011), 338.
[103] Id., 343.

the eye.[104] Therefore taking his own theory of evolutionary epistemology, he extended it to biological evolution, as he viewed both as having a "quasi-Lamarckian" character.[105] As mentioned above, this quasi-Lamarckian character arises from Popper's focus on rational selection where falsifiability serves as the knowledge process. This focus also explains his avoidance of generational change and why falsification is contrasted with Planck's Principle. Popper, like Feyerabend is much more concerned with the philosophy of science than with science. However, if the rational selection aspect of falsifiability was removed then I see no reason why generational change could not serve as Popper's mechanism, even if evolutionary epistemology would then undergo a revolution.

On the subject of revolutions, Kuhn has been mostly absent from the conversation thus far. Kuhn's evolutionary epistemology, as briefly outlined in SSR is quite similar to Popper's, yet Kuhn expressly disapproves of any teleological aspects. That being said, his mechanism of theory-choice through problem-solving ability, like Feyerabend's, requires a net gain in these abilities, albeit weighted through subjective preferences. This description of scientific evolution is not as teleological-bound as Popper's, being tethered to the preferences of scientific communities. In fact, Kuhn's entire comment on the evolutionary metaphor seems to be to stress that scientific knowledge can arise "without benefit of a set goal."[106] He uses the Darwinian metaphor to bolster his own theory rather than to compare it as a model.

Therefore Kuhn's framework may be well suited to use generational change as a mechanism for revolutionary science, but seems less well suited for evolutionary explanations. After all, he argues for revolution, not evolution. However, upon closer inspection one can

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[104] Id., 344.
[105] Id., 345.
[106] Kuhn, 173.

interpret Kuhn's distinction of normal and revolutionary science as analogous to the punctuated equilibrium theory of evolution. This theory purports that the evolutionary record shows long periods of relatively little genetic change punctuated by periods of rapid change. In Kuhnian normal science the paradigm is relatively stable; theories and problems are refined or articulated to a greater extent. During periods of revolutionary science the old paradigm disappears and a new one emerges. Unfortunately, I was not the first one to notice this parallel. Kuhn's work appears before the theory of punctuated equilibrium and therefore we can't say that he was borrowing any evolutionary analogy. On the contrary, after Stephen Jay Gould and Niles Eldredge published their 1972 paper outlining their punctuated equilibrium theory, Gould reported that several of his colleagues asked him if he had in fact borrowed the idea from Kuhn.[107] While Gould did reference Kuhn and paradigms in the paper, he does provide a defense against the accusation in his work *Punctuated Equilibrium*. Kuhn's normal and revolutionary science does appear to clearly mimic the later theory of punctuated equilibrium in retrospect and perhaps Kuhn would not have been as quick to caution against evolutionary metaphors had he known about or could have possibly anticipated punctuated equilibrium. Kuhn does not spend as much analysis on Malthusian/Darwinian competition as Feyerabend and Popper. Rather Kuhn, and as a demonstration of his similarity with Planck, appropriates the evolutionary metaphor of disappearance and emergence. In Kuhnian science, competition is only important in times of revolutionary science, where two or more paradigms are competing for puzzle-solving ability. Likewise, Planck's principle is neither Universal Darwinism nor part of any type of continuity hypothesis. Rather it is an expression of the most basic mechanisms in evolution, the change in the content or spectra of a population over time through natural

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[107] Stephen Jay Gould, *Punctuated Equilibrium* (Cambridge: The President and Fellows of Harvard College, 2007), 284.

biological mechanisms. Furthermore, Planck's Principle may serve as a mechanism under both Popper's evolutionary structure and Kuhn's structure of punctuated equilibrium. Planck's generational change principle is evolutionary in structure and can therefore accommodate other evolutionary formulations.

Any discussion of the appropriation of concepts found in evolutionary theory to other fields is bound to encounter difficulties simply from myriad aspects involved in biological evolution (competition, emergence of species, mutations, adaptation, trial and error, natural selective pressures…) and their selective use depending on the goal of the corresponding discipline or object of study. This becomes further muddled when we realize that it is not simply a Darwinian analogy yet one that transcends biological evolution and whose origin is impossible to trace or even attribute to a single source. This author thinks that we can even safely say that such a concept has emerged. Thus we may be able to account for the proliferation of such fields as evolutionary epistemology, evolutionary economics, sociobiology, bioeconomics, and others that promote a fundamentally evolutionary character in the social sciences. We may even say that it arises from a broad and long-dureé cultural concept spanning philosophy (EE), economics (Evol. Econ., classical economic theory), politics (libertarianism/anarchism), sociology (emergence), and many other disciplines. Whether these theories of order, efficiency, fitness, or freedom are all part of the same cultural milieu or appropriated their concepts from one another it lends justification to Feyerabend's thesis. Ideas and their justifications arise from an uncertain variety of sources and methods.

All the theories propose some sort evolutionary structure yet differ in form and have different implications for any description of generational change. As Kuhn cautioned, appropriating an evolutionary metaphor for scientific change can easily be pushed too far.

However if simply used as a metaphor in its broadest sense of change over time, then nothing more is said than that scientific change is change-like. So saying that science evolves must say something novel about the structure of scientific change. Scientific theories come and go, become more articulated, reformulated, or ultimately scrapped. Furthermore, theories compete against each other, not necessarily by any rational process, as Popper proposes, but for the allegiance of the scientific community. Even though Popper's evolutionary epistemology is rooted in Darwinian evolution, Popper ultimately reformulated his theory to say something about the fundamental character of biological evolution thereby bypassing human agency in scientific production and selection. His concern with epistemology yielded a rationally evolving system that ignores the influence of actual biological evolution on the activity of science. Evolutionary epistemology does not just attempt to answer the question of knowledge but also and somewhat inadvertently the question of how scientific knowledge changes. This second question is better answered through a descriptive sociology of scientific communities. Science ultimately evolves through new generations of scientists; science is a product of history just as much it is a part of it. As evolutionary epistemology also argues, science is subject to biological laws, just not through a universal mechanism as Campbell and Popper contend. It is not that evolution is a process of knowledge growth, but that evolutionary theory supports a sociologically-oriented perspective.

From these authors we can see how an evolutionary metaphor has been naturally appropriated to describe scientific change. All these concepts of science trace the change of scientific ideas as disappearance and emergence, often through a generational or evolutionary mechanism. This discussion provides a solid platform for seeing science as an evolving enterprise and to use generational change as its key mechanism for any progress. Instead of appropriating a Darwinistic metaphor, Planck's Principle can treat theories as being shaped by a biological population subject to the same biological laws that drive evolution, yet only able to reproduce through an educational mechanism. If theories can be said to evolve in some way then generational change must be the mechanism of change. A "new scientific truth" and essentially all scientific knowledge rests on an appeal to scientific authority forged out of social relations within the scientific community. This community is not just a group of consumers looking for a good theory and acting instantaneously but a shifting, drifting group of professionals flowing through their own timelines.

8. Science and Age in an Evolutionary Perspective

When examining evolutionary theories and their analysis in science, one will repeatedly come across the concept of resistance by scientists. I had previously argued that Planck's Principle says nothing about the age affecting a scientist's willingness to convert, and this is true, it does not, nor need not. But how does the diffusion of ideas occur? I also argued that age does play a role however, particularly in the transfer of scientific ideas. In the history of science large attention is often paid, as it should be, to the cultural context of the time. A scientist's age at any given time therefore ties them to a historical timeline and cultural environment which they do not identically share with any younger or older. However, the scientist must have learned their ideas from someone and will probably inform their own younger pupils of their new ideas. There is a continuity in science stemming from the constant flow of the education and rise of young professionals entering the community. The older will always be teaching the younger.

There is still another way in which the age of a scientist does not affect science but rather science affects a person's age. This idea was proposed before Popper's original *Logik der Forschung* by Gaston Bachelard in his work *The Formation of the Scientific Mind*. Bachelard's work also arises in a context of French philosophy and therefore takes a rather different approach than Popper and Kuhn's works. Bachelard does not paint science as a knowledge process like Popper, or a social activity like Kuhn, but rather as a type of psychology and scientific era. Science represents a change in the mind where natural patterns in age are overcome by adopting a scientific mindset. A more modern interpretation may state that science is a human invention, a technology which helps overcome limitations evolution has left us with. However given the context and philosophy of the argument, the age sentiment may also be less about individual biological age and more about reconciling scientific advancements with a variety of psychological backgrounds.[108]

Bachelard takes a philosophical psychological sketch of the scientific mind, which he constructs as a concept of post-1905 science. He delineates three scientific epochs, which he terms the "pre-scientific stage" of the sixteenth, seventeenth, and eighteenth centuries, the "scientific stage" ranging from the eighteenth century until 1905, and the "new scientific mind" representing post-1905 science.[109] This scientific mind rejects previous assumptions, prejudices, and does not judge based on opinion. Age therefore becomes important in Bachelard's justification for denoting this as the scientific mind. The mind is old, he says, but "when we enter the realms of science, we grow younger in mind and spirit and we submit to a sudden mutation that must contradict the past."[110] He attributes this distinction to a formative instinct similar to the sentiment of Planck as well as the cultural sense of correlating age and resistance. As the mind grows older people begin to favor corroboration over contradiction. Events in their life no longer present questions, but rather affirmations of what they already believe. It is also curious to note his use of the metaphor "sudden mutation" in his analysis. Unfortunately,

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[108] Mary McAllester Jones in her introduction to Bachelard's *Formation of the Scientific Mind*, 4-5.
[109] Bachelard, 18-19.
[110] Id., 25.

Bachelard, like most French philosophers, resisted from literalizing metaphors so he does not build upon this evolutionary scheme other than to use it as tone and context. His contention makes sense evolutionarily, as people need to be able to process all sorts of new information in order to grow; curiosity is necessary for human development. He also gives some empirical and common sense backing for why we may grow more inclined toward corroboration. His explanation relies on an appeal to intuition and is best summed up as

Empirical knowledge… engages sentient human beings via all aspects of their sensibility. When empirical knowledge is rationalised, we can never be sure that primitive sense values are not coefficients attaching themselves to reasons. It can very clearly be seen that an over-familiar scientific idea becomes weighed down by too much psychological concreteness, amassing too many analogies, images, and metaphors,…a well-drilled mind is unfortunately a closed mind. It is a product of education.[111]

This explanation accounts for Planck's rigidity in that ideas and scientific theories become familiar and that too much familiarity can be a hindrance. Moreover, theories are constructed when empirical knowledge is rationalized through a subconscious formalization. The model outlined by Bachelard in this section is the same applied by Planck in his principle; education breeds familiarity which becomes difficult to undo. This small passage also provides a number of points of similarity between Bachelard's conclusion and those of Kuhn and Feyerabend, partially from Bachelard's influence on the other two. Like Feyerabend and Kuhn, Bachelard views education as the source for intellectual rigidity albeit from a psychological perspective and not necessarily education in a formal sense.

[111] Id., 26.

Bachelard's importance also arises from his distinction between scientific periods, rather than trying to capture the essence of science throughout history. Even Kuhn's historicized science does not distinguish between revolutions in the sixteenth and seventeenth centuries and those in the twentieth. He uses the historical concept of revolution to make a broader philosophical comment on the structure of science. Kuhn's philosophy subscribes to the idea that the "history of science without philosophy of science is blind…philosophy of science without history of science is empty."[112] However, it is questionable whether the history of science can even provide enough examples to even justify attempting to construct a model for science.[113] Part of the reason is that history has trouble isolating such scientific narratives for comparison. Therefore, in terms of both generational change and rigidity of belief, periods of science must be delineated. This demarcation helps not only to form a narrative in the history of science within a historical context but also highlights different selection mechanisms within each period. Science was never a homogeneous enterprise and, if anything, has become more homogenous over time as a scientific method has been codified. Bachelard's scientific stages set up a basic frame in which to discuss intellectual rigidity through his thesis of the new scientific mind. For Bachelard, the scientific mind only describes post-1905 science because only then did science break free from the natural tendencies of the human mind such as intellectual rigidity.

It is Bachelard's appeal to these psychologically-based tendencies that reminds one of Campbell's evolutionary epistemology where science is a natural if not inevitable emergence for problem solving. While Bachelard may or may not agree with Campbell concerning his first two stages of science, Bachelard in some sense may be seen as an anti-Campbell when it comes to

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[112] Norwood Russell Hanson, "The Irrelevance of History of Science to Philosophy of Science," *The Journal of Philosophy* 59 no. 21 (1962): 580.
[113] L. Pearce Williams, "Normal Science, Scientific Revolutions and the History of Science," *Criticism and the Growth of Knowledge* ed. Imre Lakatos and Alan Musgrave (Cambridge: Cambridge University Press, 1970), 50.

the "new scientific mind." Evolution has not produced innate problem-solving capabilities that lead to a scientific mindset, but instead it's just the opposite. The new scientific mind overcomes epistemological obstacles in spite of natural tendencies. Bachelard's notion of an epistemological obstacle accounts for discontinuities in the history of science, represented by his three stages of science, and would come to influence the Kuhnian notion of paradigm shifts. With the emergence of the new scientific mind, another obstacle was overcome, and according to Bachelard, another level of abstraction achieved.

Bachelard provides a rather elegant solution to the problem of intellectual resistance in science. He simply says that the modern scientific mind rejects rigidity and therefore to do any less would constitute an unscientific mind. Kuhn's own sentiment mirrors Bachelard when he states that a scientist who "continues to resist after his whole profession has been converted, has ipso facto ceased to be a scientist."[114] The sentiment here provides an excellent opportunity to demarcate science through a psychological methodology rather than any epistemological one. A scientist possesses the new scientific mind and therefore lacks any rigidity in belief. They are forced to see things with a young mind, a mind that looks for contradictions and asks questions. This contention has been partly tested with the age hypothesis and has thus far not really been falsified. If Bachelard's first contention, that with age people look for affirmations of belief more than contradiction, is correct, then the scientific mind could account for little differences in resistance with age.

This definition of science centered on the psychology of the discipline sets up an interesting problem for Feyerabend. Such a scientific program would dispose of the inherent rigidity he sees in scientific education yet at the same time Bachelard's emphasis on abstraction

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[114] Kuhn, 159.

in the new scientific mind has a side effect of depersonalization. Feyerabend's progress relies on both individuality, for the origin of novel approaches, and on willingness to accept new ideas. Of course, other historians and philosophers of science have remarked on the positive role of resistance in pressuring emerging theories into greater articulation or exposing potential weaknesses. Resistance in this form is completely necessary and natural; it is the resistance that Kuhn talks about, not the early converts, but the hold-outs, the scientists left behind by their community, and perhaps their discipline, that the new scientific mind abhors.

It is also interesting to note that Bachelard's framework for the scientific mind mirrors Feyerabend's concept of counterinduction. Whereas Bachelard denotes the old mind as using an inductive process, searching for corroboration, the younger mind may be said to use a counterinductive process, searching for contradictory hypotheses. Feyerabend does not address counterinduction as a product of age but merely a useful logical device to show how science could, but not necessarily need to, progress counterinductively. Feyerabend, while perhaps abhorring the idea of the new scientific mind as it strives for greater abstraction would undoubtedly find solace in Bachelard's description of a youthful mind, freed from hardened concepts in theories.[115]

Bachelard's own abstraction of age and the psychology of science provokes an interesting discussion for Planck's Principle. While the principle does not present an age hypothesis, it is laden with implications for the age of a scientist. Bachelard's definition of science further epitomizes Kuhn's sentiment that some "cease to be scientists" if they unnecessarily resist. This definition and demarcation solves Planck's criticism of science by promoting the vision of a scientist as those who exhibit a malleability of belief. Planck's autobiography serves not only as

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[115] Feyerabend, 51.

an introspection of his own life's work, but also as an example of science's own introspection. Science's inward turn arguably occurred around Bachelard's 1905 designation with the emergence of relativity theory and the development of quantum mechanics. Science was forced to confront interpretation and abstraction on a different level. Furthermore, the definition of science arises from the philosophy of science. Once a discipline is mature it begins to write its history and with that comes a change in methodology through the codification, standardization, or professionalization of such a methodology or several competing methodologies. From its history, the necessity of selecting a narrative forces certain choices that end up defining the discipline. A history of the discipline is the sign of a mature discipline that allows for introspection. The oldest disciplines and trades often have the most codified philosophies, such as law, theology, mathematics, and the fine arts.

While Planck's principle is of interest to philosophers of science, age issues in science are most often addressed by sociologists and psychologists. Early studies from the psychological side have come from Anne Roe in the 1950s and '60s. She spent much of her work tracing the psychology of people with superior intellects and was drawn to the question of who becomes a scientist. She jokingly referred to the personal conflict this caused as her husband was the well-known evolutionist George Gaylord Simpson. In perhaps her most famous work, *The Making of a Scientist,* Roe traced out her survey of some of the leading scientists in several fields to whom she gave personality and intelligence tests, and interviewed about their backgrounds. She found some rather unsurprising things, such as a relatively high intelligence amongst scientists and that physicists were more introverted than their colleagues in the social sciences. Her notable results from her study on scientific activities with age came fifteen years later when she followed up her original study and published her conclusions in the journal *Science* under the title, "Changes in

Scientific Activity with Age." She focuses heavily on the many scientists in her sample who had gradually shifted into administrative positions rather than acting as researchers.[116] This seems like an intuitive and natural progression for a career in the sciences from doing research to managing research. If the age-hypothesis "Planck's Principle" is true then this structure would surely impose a nearly insurmountable rigidity as those in administrative positions would merely dictate their favored paradigm. Administration roles are also paid better than research and teaching roles, giving any scientist an incentive to limit their time researching in exchange for a more management-type role. This has the effect of removing scientists from the front-line of research in exchange for their expertise in the field and knowledge about where research is best directed and how education is best structured. However, given the pace of scientific change in certain disciplines, the expertise and relative isolation from research will weaken over time.

Oddly enough, Anne Roe and George Gaylord Simpson would co-edit the book *Behavior and Evolution* which sought to link the fields of behavioral psychology and evolution and view behavior as just as an important aspect as physiology and morphology and is invariably linked to the latter two. This idea seems vaguely related to Campbell's nested hierarchy and Roe's own work highlights intrinsic psychological characteristics within scientists. She points to an intellectual family life and a sincere curiosity as relevant factors to the "making of a scientist" rather than interest garnered through education. In fact she finds that many of those surveyed switched their studies and only settled on their occupational goals in the last years of their university study.[117] Of course, while this structure and profile of scientists may still hold some truth today, it is probably too far removed in history to be taken too seriously. These scientists grew up in the late nineteenth and early twentieth centuries in a different scientific cultural

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[116] Anne Roe, "Changes in Scientific Activity with Age," *Science, New Series* 150 no. 3694 (Oct. 15, 1965), 316.
[117] Anne Roe, *The Making of a Scientist* (Westport, CT: Greenwood Press, 1952), 230-233.

climate. The most dramatic change is easy to pinpoint – the Soviet launch of Sputnik and the beginning of the Space Race. Massive science education investment through the National Defense Education Act in the United States and a culture mesmerized with science fiction and space travel undoubtedly provided different motives for future-scientists in the following generations. Similarly, after the Space Race, when science funding collapsed, one would expect a somewhat different psychological background from the generation of scientists.

Roe also notes the importance in the psychology of the scientist because of biological limitations humans encounter in rationalizing their knowledge of the natural world.[118] The "personal factor" in science presents an obstacle to the ideal absolutist science through selective perception, cultural assumptions, and overall limited perception capabilities. Even though she writes about the biological limitations of science and behavioral aspects of evolution, her clinical psychology focus does not easily lead to Planck's Principle. Yet scientific knowledge, in the form of objective feedback from the natural world, is limited by man's biology in every way. Furthermore, it is not trivial to state that science is bound by biological limitations in humans – the philosophy of science has been grappling with this problem since its inception. Technology allowing greater experimentation frees man from some of his biological limitations in perception. Just as scientists are biologically limited in their perception, their time also limits abilities associated with judgment and justification. Given infinite time scientists could weigh all the possibilities, the entire community could be brought in, experiments could be reproduced ad nausea, great levels of abstraction attempted, and theories could be weighed against each other and justified by their original proponents. Social scientists arguably have a much harder task as their object of study changes with time. However, while science is bound by biological

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[118] Anne Roe, "The Psychology of the Scientist" *Science, New Series* 134, no. 3477 (Aug. 18, 1961), 456.

limitations, it is not always hampered by them. Limited time forces scientists to produce work in the face of competition. If Alfred Russell Wallace had not been working on his own theory of natural selection, Darwin would not have been as pressed to publish his; one may even argue that in the absence of competition Darwin's work was delayed by a decade or two.

Among the most well-known sociologists to study age in science are Robert Merton and Harriet Zuckerman. Their studies from the 1960s and 1970s highlight important demographic data on the scientific community. As mentioned earlier, Merton associates Planck's Principle with an age hypothesis yet ultimately rejects such a hypothesis based on the data.[119] Age and aging in the sciences is rather important in terms of social structure though. Merton and Zuckerman point out that older scientists naturally take on the role of status gatekeepers for scientists, meaning that they essentially welcome any new members to the scientific community. Likewise, whereas (at the time of their study), most scientific personnel were younger than 45, most of the decision-making was made by those older. Zuckerman's book, *Scientific Elite* also highlights the social hubs created around such scientists and noted that while older scientists on average tended to cite less-recent works than younger scientists, Nobel Prize winners betrayed the trend .[120]

Age, while unaddressed in the literal Planck's Principle, does play a significant role in evolutionary theories and scientific resistance. A new generation can only grow up familiar with a theory because of a generational transaction of education where a necessarily older generation passes on knowledge to a necessarily younger one. Education is a central point in both Kuhn and Feyerabend's work precisely because it is seen as the most important issue. The next generation is always the new battleground of ideas. Taking into account Bachelard's notion of science

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[119] Robert K. Merton, *The Sociology of Science* (Chicago: University of Chicago Press, 1973), 514-515.
[120] See Harriet Zuckerman, *Scientific Elite* (London: Collier Macmillan Publishers, 1977).

freeing a person from the normal bias of age, Roe's studies on the psychology of scientists, and Merton's conception of the sociology of science a very different picture is painted than Hull et al's interpretation of Planck as generational conflict. Instead we get a picture of science where age does matter, at least in the selective-retention aspect. Older scientists are not stubbornly rejecting new viewpoints, yet play a role in managing and transferring knowledge to their pupils. In some laboratory-driven fields the education of scientists even often takes the form of an apprenticeship. This transfer of knowledge, ideology, or methodology becomes the driving mechanism in any descriptive evolutionary theory of science as it is in Planck's Principle.

9. Multiple Discovery

Evolutionary and generational scientific change has found fertile ground in the major philosophers of science and in much more than simply a metaphorical way. It may be found in the evolutionary structures that each places on scientific development and through a broader principle of self-organization and efficiency. We have also seen that although such a structure does not imply an age hypothesis, age is an important factor in more sociological-laden theories of evolutionary change. The discussion of Bachelard has even shown how age (of the mind at least) may be used metaphorically and tethered to notions of scientific resistance. Building on the topic of resistance we should look to two specific phenomena in science that also build on an evolutionary structure, multiple discoveries and scientific controversies. These characteristics of science address both the generation of ideas in multiple discovery and the process of the selection of ideas in scientific controversies. Both topics have trouble fitting into traditional explanations of science. Depending on which philosopher of science you consult, multiple discoveries should either never happen or happen all the time if not due to some unnatural constraint. Similarly, philosophers would disagree on whether scientific controversies should exist or whether not enough exist.

To begin, the term multiple discovery needs some clarification. Multiple discovery traditionally serves as the antithesis to the "genius theory" of discovery where breakthroughs occur because of one person's unique insight. Instead, multiple discovery theory proposes a pattern of scientific progress occurring through individual simultaneous developments where two or more scientists, working separately, come to the same conclusions, same theory, or same discovery. Both theories may also refer to technological developments as well. However, the connotation of multiple discovery may be somewhat misleading depending on the background one is working with. Discovery implies finding something new and novel so multiple discovery seems a little counter-intuitive to begin with. Strict social constructivists might even find the term abhorrent for this reason, but the term "multiple construction" sounds too much like a large infrastructure project. Therefore the whole term then has a lingering connotation of these discoveries being mere coincidences and unrelated to one another. Several authors have argued that multiple discovery, when the cases are examined in detail, are not really multiple discoveries at all but in retrospect appear to be the same.[121] This approach seems inappropriate though as nobody would expect two coincidental theories to be identical, or even to share all core concepts. Instead, multiple discovery hints that the ideas shared enough similarities to warrant some explanation other than a mere coincidence. So perhaps a better description of such a phenomenon is "simultaneous emergence." I will still use the term multiple discovery out of

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[121] For instance, see Don Patinkin's "Multiple Discovery and the Central Message," *American Journal of Sociology* 89 no. 2 (Sept. 1983). He argues that multiple discovery theory is hampered by an imprecise definition of multiple discovery and ignoring the "central message" of the scientists involved. Neither of these points negates the thesis that multiple discovery is the natural pattern of scientific progress and may arise from the misconception in the definition.

convention but will hope to show that simultaneous emergence is what really occurs and that it is supported by, and supports, generational change and relies on an evolutionary conception of science.

It should also be noted at this point that the discussion thus far has centered almost exclusively on the context of justification. An analysis of age in science on creativity and productivity will naturally stumble into the realm of discovery, yet the real concern is not how theories arise but how they persist and survive. Popper even attributes the "logic of discovery" as a problem best addressed by psychology.[122] While Kuhn, and Feyerabend to a lesser extent, blur the distinction between the contexts of justification and discovery, the evolutionary analogies used by both focus more on the "selective retention" aspect than the "blind variation" aspect of scientific change. Nonetheless, the central importance of puzzle-solving in the theories helps to guide the discovery process providing at least some rationale behind it rather than labeling it as strictly psychological or pure chance. Even Planck's Principle, when removed of its ageist interpretation focuses solely on the context of justification. However, like the connotation involved with multiple discovery, the problems stirred up by creating such a distinction are mostly phantom ones. For instance, having a context of justification implies that the way a theory takes hold is through a rational justification. Well of course this contradicts Planck's mechanism and so perhaps a better distinction, if we are forced to make one, would be calling it the "context of closure."

Multiple discovery sounds like a useful notion and can add to the present discussion, but how close does it resemble reality? The Genius Theory's romantic appeal stems from the parallel traditional Great Person Theory of History and those unique scientists in history who

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[122] Popper, 31-2.

lend proof to such a theory. There is strong evidence to support multiple discovery as the "normal" way science progresses, but to say it's the only way would be far too brash. Episodes in the history of science such as Einstein's *Annus Mirabilis* serve as a constant thorn in the side to multiple discovery, but these instances do not prove the genius theory of discovery but only that history does contain flashes of brilliance from time to time. Nobody in history was ahead of their time, all are products of their time and some influence history enough that their ideas persist long after they are gone, giving the illusion that they were ahead of their time. Similarly there are no zombie scientific theories, no theory comes back from the dead. No theory is really ahead of its time. Any theory that "comes back" is always a re-interpretation of the original in the present as well as a re-interpretation of the old theory historically to conform to the new one. Scientific and technological developments are never a total break from the past. Einstein's special relativity did not render Newtonian motion irrelevant or disprove it, but just gave it a new interpretation. Similarly, Darwinian evolution built off of and served as a response to other well-established theories of evolution.

As mentioned earlier, detractors of the multiple discovery theory have pointed to the problem of what exactly constitutes such discoveries and how are we able to equate two or more theories to make them multiple? Even proponents have pointed out that "there is a large element of social and historical construction in the identification of discoveries."[123] This is certainly the case for many, if not all, apparent multiple discoveries. The more an idea is simplified into one aspect or another, the more it will have in common with other ideas and thus we are able to find a wealth of papers and books comparing ideas of various people who are otherwise completely unrelated by history. Many philosophical or scientific ideas inevitably get traced back to

[123] Augustine Brannigan and Richard Wanner, "Historical Distributions of Multiple Discoveries and Theories of Scientific Change," *Social Studies of Science* 13 no. 3 (Aug. 1983), 420.

Aristotle, even fairly recent notions such as subliminal perception.[124] This paper is even guilty of hinting that evolutionary theories of scientific development developed independently. Even these theories, in a loose sense could be considered multiple discovery, yet these are obviously connected through an appropriation of the evolution analogy. However, such common roots may not be unusual for multiple discoveries. In economics, a Marginal Revolution occurred in the last quarter of the nineteenth century in which classical economic theories were reformulated, using marginal utility as a key market-clearing mechanism. However, this was not a collaborative effort between economists but occurred independently through Carl Menger in Austria, William Stanley Jevons in England, and Leon Walras in Switzerland all within three years of each other. It may seem like an astonishing coincidence, yet Philip Mirowski, in *More Heat Than Light*, has pointed out the recent developments in thermodynamics at the time whose mathematical formulations were appropriated wholesale by the economists.[125] Multiple discoveries not need be related to each other this directly, but often there is a common cause for the emergence of them. Robert Merton even notes that multiple discovery was, itself, multiply discovered, and therefore calls it a "self-exemplifying hypothesis."[126]

Some empirical studies have also been attempted to show multiple discovery, or at least to show that discoveries cluster rather than exhibiting a random chance pattern. Brannigan and Wanner (1983) show that the pattern of historical discovery occurs in the form of zeitgeists, or that developments in particular fields tend to occur in clusters, hinting at some common cultural context that provides fertile ground for such discoveries. They conclude that the economic structure of science is key for such discoveries, particularly stressing communication between

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124 N.F. Dixon, *Subliminal Perception: The Nature of a Controversy* (London: McGraw-Hill, 1971), 6.
125 See Philip Mirowski, *More Heat than Light*, (Cambridge: Cambridge University Press, 1991).
126 Merton, 352.

scientists, the less communication the more likely the case for duplication.[127] The authors also speculate that as disciplines are more established there will be less chance for multiple discoveries as the fields of research become more specialized and narrow, relying on a notion of knowledge accumulation within disciplines.[128] While communication between scientists will certainly decrease the number of multiple discoveries, it does not change the fundamental nature that brings about their rise to begin with. Instead it nips the possible blossoming of discoveries in the bud. Once a discovery is made public, those pursuing the same line of research will likely give up their pursuit or modify it to go in a different direction. Furthermore, conferences, journals, and other forms of communication may bring people together with similar ideas that may have each emerged independently but now emerge in a collaborative effort. Scientific pursuits that revolve around industry, such as discoveries made in pharmaceutical research are structured to negate the possibility of multiple discoveries. Even if two scientists, or labs, are working on a similar development, the first to publish or to reach the market takes the spoils. This structure is further reinforced by the patent system. Intellectual property rights incentivize scientists to keep communication about research paths open while keeping the research itself hidden.

Brannigan and Wanner's article shows the importance of communication in the appearance of multiple discovery events and in many ways it is common sense. The more important issue is why multiple discovery is the natural pattern of science in the absence of communication or other limiting characteristics? The philosopher Arthur Koestler, perhaps most famous for his works on creativity, does not even see multiple discovery that remarkable, pointing out that the Newton-Leibniz multiple discovery of calculus was merely two out of a

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[127] Brannigan and Wanner, 429.
[128] Id.

million rather than one out of a million.[129] Instead, the limitations imposed by communication and education inhibit more multiple discoveries. Authors Lamb and Easton point to such bindings as the foundation for an evolutionary interpretation of multiple discovery. While there are no instances of evolution producing the same organism in different places, similar organic structures and organs have evolved independently and one could view this as a multiply "discovered" problem-solving mechanism. If Brannigan and Wanner are correct in their analysis that scientific discoveries follow a zeitgeist pattern one may see how an evolutionary mechanism fits. A cultural approach to explain these discoveries implies a generational shift , where the cultural climate would produce a new generation that would have enough in common to come to similar conclusions given the current intellectual state. Lamb and Easton express similar sentiment, emphasizing the cultural concerns that young scientists bring with them into their work and eventually into the field as a whole.[130] Furthermore, they reference other authors who view such discoveries as inevitable if only because so many scientists pursue similar lines of work.[131] These factors naturally lead to multiple discoveries, but does it necessarily give them evolutionary characteristics?

Multiple discovery can easily be molded within an evolutionary conception of science yet Lamb and Easton take it a step further and argue that it supports a position of evolutionary realism in science.[132] By this term they mean that the process of science, while evolutionary or guided by the flow of history, also has a certain real independence to it through the genius and the individual. This independence leads them to adopt a Lamarckian model of the scientific process as the selection process becomes subject to purposeful or non-natural constraints. The

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[129] Lamb, David and Easton, S.M. (Eds.). *Multiple Discovery* (Townbridge: Avebury Publishing, 1984), 23-24.
[130]Id., 23.
[131] Id., They reference De Solla Price who compares scientists to apple-pickers all reaching for the same fruit.
[132] Id., 26.

generation of new theories emerge from long processes and evolutionary pressures but survive based on more rational means. Lamb and Easton even point out that Popper, while considered a rationalist in the survival of theories, leaves the context of discovery open to any means of interpretation.[133] This distinction is further amplified in the "blind-variation and selective-retention" separation in evolutionary epistemology. The theory of multiple discovery asserts that the context of discovery, or the individual genius, provides the impetus for variation and the authors cite revolutionary hypotheses as analogous with mutations. However, they would not call these blind-variations at all but that scientific knowledge does, at least to some extent, accumulate, and such theories and skill sets are passed between generations.

People often find the idea of multiple discovery abhorrent because it implies that ideas really are not novel. It reduces the action of humans to organisms within their environment; geniuses aren't geniuses individually but rather may represent the flowering of a cultural sentiment within an individual. A multiple discovery need not necessarily take such a harsh view of creativity however. Instead, the hypothesis proposes that everyone above a certain threshold may be able to propose a revolutionary hypothesis if not inhibited by certain limitations through either communication, education, or other more nuanced psychological rigidities. Multiple discovery also appeals to how history is organized when historical mechanisms exemplify similar evolutionary mechanisms.[134] The struggle in the discipline of history has been how to balance out the effects of individuals in the Great Person theory of history with broader movements which may be categorized as long-durée characterizations.

An evolutionary metaphor has found fertile ground both in explaining multiple discovery as well as supporting more evolutionary or emergent characteristics present in science. It may be

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[133] Id., 32.
[134] Id., 25.

somewhat surprising then that the evolutionary metaphor is also applied to scientific controversies. On closer examination these represent two different aspects of evolution, multiple discovery borrowing from the blind variation aspect and scientific controversies springing from an analysis of the selective retention aspect. It may be no surprise then, that Donald Campbell also studied multiple discoveries, seeing them as characteristic of evolutionary epistemology.

10. Scientific Controversies

Thus far we have seen evolutionary theories of science, the problem with them, and the ways in which such theories and multiple discovery theory mutually support each other. However, the core issue in Planck's Principle has still been mostly been ignored. While Planck was describing the creation of a new scientific truth, the sentiment behind the statement is just as much about the resolution of controversy. Planck's Principle might exist as a truism in the most literal sense but the importance comes from how we should interpret such controversies, and in fact much has been written about the subject. In a 1987 work seeking to catalogue some controversies and articulate the nature of scientific controversies, Tom Beauchamp outlines five types of closure in such controversies. He sees closure occurring either by sound argument, consensus, procedure, natural death, or negotiation, all categories constructed from the works of earlier authors.[135] As the editors show in the work, these designations may apply to case by case instances, often dealing with specific controversies within small scientific communities. For instance, a contributing author notes that the Lysenko Affair could easily be described as an instance of procedural closure by its ultimate appeal to authority.[136] They also note that such categorizations imply both a narrow and broad interpretation, in which one could analyze the

[135] Englehardt, H. Tristram Jr., and Caplan, Arthur L. (Eds.), *Scientific Controversies* (Cambridge: Cambridge University Press, 1987), 5.
[136] Tom Beauchamp, "Ethical Theory and the Problem of Closure," *Scientific Controversies* (Cambridge: Cambridge University Press, 1987), 31.

type of closure in a specific historical instant or view it from afar as characteristics of a particular community or as preferences for a particular type of argument.[137] From first look at the different types of closure, Planck's Principle and evolutionary scientific change seem most in line with natural death closure, however the description of such closure is a bit different. The editors equate Beauchamp's natural death closure with a loss-of-interest type closure, or abandonment closure. This type is distinguished from the others in that it is not marked by any actual act of closure, the controversy instead simply disappears. Planck himself commented on this type of closure, calling them "phantom problems" in science.[138] Planck cites the disappearance of theories about Chrysopoeia, or the belief that base metals could be transformed into gold as one such problem. Beauchamp offers further examples such as controversies stirred by Aquinas's *Summa Theologica*.[139] So in this sense both the proponents and opponents of a theory simply die off with nobody to take up their cause afterwards. This type of closure may more appropriately describe political or ideological developments rather than scientific ones but these are certainly relevant to early science. Newton and Leibniz's debate over God's role in the structure of spacetime soon disappeared from the absolutist-relationist controversy in the spacetime debate. In this particular case it would seem that the controversy emerged as a sub-controversy, emerging only in the arguments against a larger theory and therefore disappeared after Newton's absolutist conception triumphed in the 18th century (mostly due to the death of Leibniz oddly enough). However, if scrutinized more closely, natural death closure appears to not really fit anything that could be called closure. This point is acknowledged by Beauchamp and attributed to a similar criticism offered by Richard Giere. For instance, arguments in the Newtonian Clarke

[137] Englehardt and Caplan, 8-9.
[138] Planck, 52.
[139] Beauchamp, 32.

and Leibniz correspondence and those in the *Summa Theologica* never achieved closure even if their parent controversy did. The very reason for the controversy's existence disappears. Similarly, the Chrysopoeia controversy was not simply abandoned but was instead segregated from professional chemistry; its abandonment was defined procedurally. On the other hand, if simply following the problem of interpretation proposed by Beauchamp, natural death closure could be interpreted broadly to imply all types of closure in that all types of closure eventually result in the abandonment of controversies with the caveat that often one side will abandon the controversy first. With no controversy left to pursue the other side will also abandon and new scientists will not even be cognizant of such a past controversy. Natural death closure simply implies all types of closure. It's not so much that scientists at the origin of the controversy lose interest but that the interest is lost through time and collective memory, through new generations simply being unaware of any controversy. At the macro level, all controversies end this way.

Perhaps part of the departure from the micro analysis comes from what is meant by closure. In the volume, Tom Beauchamp, while acknowledging myriad connotations and definitions, loosely defines it as, "an outcome, not a process, for closure is the termination of a controversy."[140] His categorizations of closure denotes the processes that occur to cause such closure and, by extension, the sense of closure at the end. Yet closure may only be determined retrospectively. Even the most clearly recognized acts of procedural closure, such as court rulings, rarely settle issues. The M'Nagthen Rules to establish insanity in the courts of Britain did not settle psychiatric definitions of insanity, nor did the recent ruling in Kitzmiller v. Dover settle the controversy surrounding evolution. Similarly, controversies settled authoritatively, through political means, will only be settled as long as the political establishment exists, but

[140] Id., 28.

often not even this long. Controversies can only be said to have been resolved when they no longer exist within the relevant communities but this again does not necessarily mean that the controversy is gone forever. However, it is also pertinent to suggest that any controversy that reemerges would have a distinctly different character and context than the original and therefore may just comprise a different controversy altogether, perhaps even feeding on some still unanswered problems from the first.

Natural death closure in the broad sense then may be interpreted as closure by Planck's Principle. Closure occurs through the loss of collective memory and creates what Bruno Latour calls a black box in science, a presently-resolved theory used as a fact to produce other knowledge. Despite Planck's own sentiments about absolute science, his principle's notion of closure is self-defining without any need to define what Planck means by a "new scientific truth." Or, in other words, the new scientific truth is simply defined from closure and occurs with the tacit acceptance of a new generation rather than at any time before. Controversies therefore do not simply follow the traditional narrative of two distinctly demarcated camps in a contest over ideas but of shifting communities losing old members, gaining young members, and seeing a flow of converts and émigrés. In a more recent volume on scientific controversies, author Philip Kitcher also points out that a problem with scientific controversies is that "many scientific disputes *evolve*" (italics in original).[141] The main point being that controversies often span generations and involve numerous groups and actors with the same controversy being resolved for one group and open at the same time for another. The debate over knowledge production through experimentation, as detailed by Shapin and Schaffer in *Leviathan and the Air Pump*, and of prominent discussion in the context of Boyle's experiments is not yet fully resolved or dead.

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[141] Philip Kitcher, "Patterns of Scientific Controversies," *Scientific Controversies* ed. Peter Machamer, Marcello Pera, and Aristides Baltas (Oxford; Oxford University Press, 2000), 22.

Philosophical circles, social constructivists, theologians, and physicists still question the supposedly simple and resolved question of what experimentation produces. This evolution can really only be caused by one thing and that is the changing collective intellectual spectrum in the communities. When working on longer scales of time, as scientific theories are often prone, biological evolutionary mechanisms overtake sociological functions and the new generation dictates the current state of any controversy. Furthermore, this sociological-biological distinction mirrors the evolutionary distinctions made by Lamb and Easton and the general mechanisms of history. The state of any theory is solidified through some passage of time. The Annales school of history distinguishes the long durée histories from those that pay attention to events, Lamb and Easton propose that the broader process of evolutionary development of scientific theories are punctuated by important events in the success of geniuses, and the passage of generations provides a broad definition of closure when juxtaposed against any sociological acts such as procedure or consensus.

Closure occurs for many reasons, but the mechanism of closure must be Planck's Principle, if taken as a case by case example all controversies are ended by natural death closure. Procedural closures, such as a court ruling or decree from scientific authority, do not necessarily end controversies and these scientific controversies may only be placed into any category retrospectively through a specific historical interpretation. Darwinian evolution reached consensus closure a decade after publication of the *Origins*, several sound argument closures throughout the years levied at specific criticisms of the theory, and procedural closure in the court cases of recent years yet the controversy remains. If closure can only exist within the community then closure will surely occur for different relevant communities; just as theories are not absolute, neither are their closures. Each community will achieve closure differently and new communities may arise in similar traditions of the old ones.

Now we can ask whether Planck's Principle is a more meaningful designation or description of scientific closure. It must be admitted that describing science as evolving through generations of scientists has very little narrative appeal. There are occasions when the main opponent or proponent of a theory dies and so with it the theory. Such was the case in the Clarke-Leibniz correspondence where after an exchange over the absolutist nature of space, Leibniz's death essentially ended the controversy. There are also instances when generations of scientists came to dictate their field through Kuhnian revolutionary science, resolving controversy by overthrowing established thinking. The rise of the experimentalists in Restoration England is well documented in Shapin and Schaffer's work on Boyle and Hobbes and shows how such a subculture in science might lead to Kuhnian change.

These are some nice examples where Planck's Principle may easily be invoked but it still does not explain the principle's greater appeal. Instead we should look at what happens with scientific controversies when the distinction of scientific communities is not taken for granted. In any scientific controversy who's views are to count and who's are to be discarded, or which scientists are given the status of experts above all others? If a controversy is isolated through either nuanced detail in a theory or specialty in a field, then it will be pretty clear if a consensus can be reached. Those outside the field are simply unprepared, nor would they probably want to, comment on the status of the theory. Similarly, the scientific community in the controversy may be defined by a professionalization of the field. Only those already expressly accepted by a scientific organization will be able to comment on a particular theory. Early scientific societies, like the Royal Society of London, and more modern medical societies like the American

Psychiatric Association serve as good examples of how controversy may be easily resolved through such organizations. But what if a controversy is not simply isolated by expertise requirements or professionalization? Often times, a controversy will transcend different fields either through its appeal to different theories or sentiments or by its implications for other theories or ideologies. There are two natural reasons why any scientific controversy today immediately breaches the boundaries of any normal scientific community. First, much of science is funded through public funds. Scientific research may only be funded if it first receives approval of those funding it and therefore any controversy will draw in the public to guide the research surrounding it and weigh in on the conclusions. Such was the case in the early 2000's when, upon the Republican Party gaining control of the US government, the Bush administration imposed a ban on all funding for stem cell research due to ethical concerns raised by the traditional Republican base. Similarly, the products and applications of any scientific research may become inextricably tied to policy decisions wherein the theory behind the science is not questioned so much as the feasibility and economic cost-effectiveness of pursuing the research publicly. The current and protracted debate over nuclear power in the West takes this form where the scientific theories behind fission reactions are not questioned so much as the public policy implications of implementation. Furthermore, controversies over the safety of certain drugs or new food products ask questions that go beyond just science. Second, science itself is controversial among many ideologies either because it contradicts them or because it is at least perceived as being at odds with a particular ideology. Among many religious populations, science is outright distrusted because of the perception of scientists as either atheists, materialists, or humanists, all seen as antagonistic to many of the mainstream western religions. In the United States these issues have become part of what has been dubbed by traditionalists as a "Culture War" between religious conservatives who often hold the Bible as the literal word of God and secular progressives. Richard Hofstadter has even proposed the thesis that a large section of America is anti-intellectual and therefore naturally antagonistic to more specialized professions that claim a unique access to particular knowledge.[142] The democratization of the Bible during the Reformation supported the view that any knowledge should be easily open for anybody to know and interpret. So even though science may claim the availability of the knowledge to everyone, it unfortunately rarely works in such a way.

When scientific controversies go public, the rules and patterns are different and mechanisms of scientific change do not obey the standard vision of ideal science; scientists may feel a need to favor objectivity above all else yet the public certainly does not. These cases may simply be distinguished as simply controversies rather than scientific controversies, yet for reasons already stated, the line between both is blurred by the ambiguity of what constitutes the scientific community. The broader the theory proposed, the broader the communities become. Therefore asking whether humans are causing climatic changes in the earth becomes a much easier question for more people to understand than asking how data gathered from Antarctic ice cores should best be interpreted. The more nuanced issues of any scientific theory will get addressed first and most thoroughly by those within a more narrowed scientific community while broader answers will come from those most removed, answering questions more about implications or the grand sentiment of any theory. Public opinion in scientific controversies is not always wholly present yet often driven by media coverage as well as simply the portrayal of science in popular culture. For instance, the recent and much-publicized experiment that appeared to show neutrinos travelling faster than the speed of light was picked up by many

[142] See Richard Hofstadter, Anti-Intellectualism in American Life (New York: Knopf, 1964).

internet and news organizations as a testament to the possibility of time travel.[143] While the much more narrow scientific report quite clearly concludes, "We deliberately do not attempt any theoretical or phenomenological interpretation of the results."[144] The public will in effect provide a commentary on scientific theories and sometimes the commentary will lead to controversy, that may yet be absent in the scientific community. In the case of the neutrinos it may lead to a resurgence of time travel movies.

The mass media's role in shaping scientific controversies is mostly acknowledged due to its ability to interpret between the public and the scientific community. The mass media is thereby just one mechanism by which controversies reach and are formed by the public, another major mechanism is by laws. Even in open, relatively transparent, democratic societies people are still mostly unaware of how new scientific findings are incorporated into law. This process may either occur directly through legislation, or indirectly through introduction of scientific expertise and evidence in court cases. For instance, merely attempting to use DNA evidence in the courts is still a matter of controversy and any other scientific examination required by the case will undoubtedly draw in scientific experts on both sides. Recently and related to mass media, scientific controversy surfaced in the trial of Dr. Conrad Murray, the doctor of the pop singer Michael Jackson, when experts from both the plaintiff and defense gave contradicting testimonies on the administration and lethality of the sedative propofol.

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[143] See as one example: "'Faster Than Light' Particles Make Time Travel Possible, Scientist Says," Foxnews.com, 23 September 2011 http://www.foxnews.com/scitech/2011/09/23/faster-than-light-particles-may-be-physics-revolution/ (last accessed Dec 11 2011).

[144] Dario Autiero et al., "Measurement of the neutrino velocity with the OPERA detector in the CNGS beam,"*Journal of High Energy Physics* (Nov. 17, 2011), 22.

11. The Evolving Public Evolution Controversy

The recent controversy surrounding the teaching of Intelligent Design in schools alongside and as an alternative to evolution provides a nice example with which to apply Planck's Principle in the face of scientific controversy. The example is wholly appropriate for a number of reasons. First, the controversy, while originally scientific, has now expanded into a cultural controversy and the public nature of it often outweighs the scientific nature of it. Planck's Principle may be more appropriate to describe non-scientific attitudes, especially surrounding scientific controversies where the ideas take on a certain cultural inheritance. Second, the debate over evolution is focused specifically on early education, or trying to expose children to a particular view early on. The focus of the evolution-creation controversy, since the Scopes trial, has also strictly focused on educating children rather than attempting to convince their opponents and each generation may be dictated by the curricula put forth by schools over the years. This aspect is of the utmost importance in demonstrating the mechanism of Planck's Principle. Third, legal rulings over the years dictate the character of the controversy and with the educational aspect of the controversy imply a type of generational shifting. If one is to talk about generations then it should be done through events that can only retrospectively categorize a certain generation. It is a historical tool of analysis, similar to evolution. Fourth, many of the arguments from philosophers of science like Kuhn, Popper, and Feyerabend play a key role in the public debate between evolution and creationism or intelligent design. Often the question is asked whether evolutionary theory is scientific or whether intelligent design is scientific and proponents on both sides turn to the philosophy of science for answers. Similarly, the controversy itself is about science and often will take arguments from the philosophy of science to demarcate science. And finally, evolution has been examined as a metaphor throughout the paper thus far and so, like multiple discovery, the evolutionary characteristic of scientific change may too become a self-exemplifying hypothesis. Evolution itself has a fairly controversial history within the scientific community and mostly removed from creationist counter-theories. Furthermore, evolution partly becomes controversial due to its more metaphorical context of change over time. Notions such as cosmological evolution, chemical evolution, and social Darwinism, among others all stirred further controversy by stigmatizing the biological theory of evolution through their own appropriation of it. Biological evolution becomes conceptually linked with other forms of evolution when it makes analogies between the two, and often the public's understanding of biological evolution is skewed by mechanisms and loose metaphors within other forms. We will see that even strict young earth creationists accept evolution at some level as biological change over time.

While volumes have been written about the history of the controversy surrounding evolution covering all the naturalistic theories before Darwin and all the arguments over more specific mechanisms, the public controversy has really only emerged in the late twentieth century. Many of the scientific arguments formally made against Darwinism were appropriated by intellectuals leading the public charge, like the alternative theory of Catastrophism, yet they took on their own distinct forms in the public sphere through Creation Science studies. Darwinian evolution in the scientific community meanwhile has reached, at the very least, a broad consensus on common descent with modification, although there have been disputes over the years, most recently with epigenetics challenging the interpretation of the theory. Some of these, like punctuated equilibrium remain unsettled or are lumped into the column of being phantom problems. So for all practical purposes, the history of the creation and intelligent design controversy begins when it moves to the educational and courtroom setting. In the United

States this began in the 1920's when youth first started attending high school en masse. While the evolution controversy is not confined to the United States, it certainly is the center of such debate in the Western world, mostly because of the large proportion of fundamentalists in the US population. An oft cited 2005 study from Michigan State University placed the United States 33rd in percentage of the population that accepts the theory of evolution among 34 western nations.[145] Only Turkey, with its own large fundamentalist population, had a lower acceptance rate. When one talks about the public controversy over evolution in the Western world, the US generates the vast majority of it.

Thus the "Scopes Monkey Trial" from the late 1920's, marks the beginning of a prolonged presently raging public controversy. The trial took place in Dayton, Tennessee when a school teacher, John Scopes, was brought up on charges for teaching the theory of evolution in his high school classroom. Years earlier, the state of Tennessee had passed the Butler Act which had essentially prohibited the teaching of evolution in the state and set punishments for any teacher who did. Scopes eventually avoided the punishments on appeal through a technicality, yet Tennessee's law was upheld as constitutional by the state supreme court. The US Constitution, in the Establishment Clause of the First Amendment proclaims that the government can "make no law respecting an establishment of religion, or prohibiting the free exercise thereof." How this has been interpreted has varied over the years, yet in the Scopes trial it was determined that the Butler Act did not favor a particular religion nor gave one religion preferential treatment over the theory of evolution. The trial itself pitted religious fundamentalism against modernism. The prosecution argued against the harmful effects of teaching evolution to children while the defense argued the compatibility between evolution and

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[145] Jon D. Miller, Eugenie C. Scott, and Shinji Okamoto, "Public Acceptance of Evolution," *Science* 313 (August 11, 2006), 765-766.

religion and against the literal interpretation of the Bible. The trial itself eventually culminated in William Jennings Bryan, the lead prosecutor and a noted politician, taking the stand to be questioned as a Bible expert. After the trial, there emerged a bit of a stalemate in the controversy; fundamentalists had won the trial the result of which was ridiculed throughout more modernist states in the north. Furthermore, Bryan, the fundamentalist movement's leading anti-evolutionist figure, died five days after the trial concluded. The battle over evolution in the schools was over but the leader was now gone. After 1925 a few other states passed or tried to pass laws forbidding the teaching of evolution, yet most high schools simply avoided the subject and left it to the universities. Therefore 1925 represented a hugely significant year in the public controversy surrounding evolution, marked by both an important court ruling and an important death.

The following decades were relatively quiet, partly because of the ruling and Bryan's death, but also because the US had entered the Great Depression in the 1930's and the Second World War following the downturn. Little controversy really occurred until the 1960's, yet it is important to note one US Supreme Court ruling in 1947 that would have tremendous impact on how cases teaching evolution are litigated. In *Everson v. Board of Education*, the US Supreme Court essentially merged the Establishment Clause of the Constitution, which prohibited federal government action in matters of religion, with the 14th Amendment to the Constitution, which guaranteed equal protection under the law. The resulting judgment said that while individual states had been promoting certain religious views, they violated a person's rights under the 14th Amendment. This ruling now meant that states could not advance any particular religious viewpoint. The result opened up a flurry of lawsuits against state religious violations yet the prohibition on evolution still remained untouched for some years.

The Butler Act met its end in 1967 but not by court ruling. Under threat of a teacher bringing a lawsuit, the legislature of Tennessee quickly passed a bill nullifying the act and the teacher teaching evolution was allowed to keep his job. The first major court challenge came the next year in the neighboring state of Arkansas which had passed a similar law to the Butler Act. In *Epperson v. Arkansas*, the Supreme Court essentially overturned all laws prohibiting the teaching of evolution through the new found power in the Everson ruling. They argued that prohibiting teaching evolution violated the Establishment Clause because it gave preferential treatment to a certain religious view and thus evolution was able to find its way into high schools throughout the entire country and everybody under 60 now accepts the theory. Of course, that's by no means true, nor did the ruling provide the end to the controversy.

Edward Larson, like many other public evolutionist proponents, is quick to point out the evolution of creationism.[146] He proposes a simple explanation of three stages of creationism in the public evolution controversy. The first, as we have just read, was an effort to prohibit evolution in the public schools which lasted until the Epperson ruling in 1968. From the 1960's until recently, the creationist approach focused on finding ways to balance the teaching of evolution with some form of creationism. The last stage, and only recently emerging, yet not wholly original approach, is to teach evolution as just a theory or to teach science criticism in science classes that focus on certain subjects, evolution naturally included amongst them. Larson's outline provides a useful framework for approaching the controversy and is particularly relevant for the discussion of evolving theories as each new approach represents not only shift in creationist theories but provides useful generational markers around them. Larson's own description of the Scopes aftermath resembles a Planck's Principle type mechanism: "Both sides

[146] Edward J. Larson, "The Classroom Controversy," in *The Panda's Black Box* ed. Nathaniel Comfort (Baltimore: Johns Hopkins University Press, 2007), 66.

effectively communicated their message from Dayton – maybe not well enough to win converts, but at least sufficiently to energize those already predisposed toward their viewpoint."[147] As briefly mentioned earlier, the public evolution controversy focuses primarily on what is taught to the next generation in the schools. The goal on both sides is not necessarily to convert people to their view, but to teach the right thing to the next generation.

Building within Larson's narrative, a new challenger from the anti-evolutionists emerged around the same time of the Epperson decision in the form of the Creation Science movement. While much of the theory and arguments behind the movement may be traced to Darwin's first opponents, or even predecessors, it was greatly popularized as a serious alternative by Henry Morris, a hydraulics engineering professor at Virginia Tech. Creation Science essentially espoused the same literal interpretation held by Bryan but also proposed explanations for much of the empirical evidence evolution was based on. It further attempted to use science to prove the literal interpretation of the Bible. Of the two aspirations, the movement had much more success with the former. Creation Science holds a young-earth view with a belief that the Bible can explain both the fossil record and account for numerous species alive today. They base this view on the belief that the flood mentioned in the book of Genesis was so great that it caused the geology we currently see on Earth. For instance, they maintain that when the flood resided the simplest organisms settled on the bottom while more complex ones settled on top thus creating the strata found in rock. Creation Science also accounts for the variety of species on Earth as all having evolved from one "type" of animal, each of which were saved on Noah's Ark. Therefore they do maintain some sort of evolution in their conception but it takes a highly contrasted form to Darwinian evolution. The Biblical explanations of geology may have been novel at the time,

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[147] Larson, 70.

yet the notion that geology is created through floods was borrowed from Georges Cuvier, a French naturalist and predecessor of Darwin who argued for the theory of Catastrophism. This theory held that geology could essentially be explained and was shaped through a series of catastrophic events. The movement of Creation Science picked up where Bryan and the fundamentalists the previous generation left off, yet now confronted with the task of getting creation into the schools rather than getting evolution out. Rather than simply promoting a negation of evolution, Creation Science had its own methodology and object of study even if the purpose was to often lob attacks at evolutionary theory. The creationist movement in many ways moved from simply dismissing evolutionary theory, to creating their own theory to answer the questions that evolution posed to their theology. An industry built around Creation Science also bloomed and still continues until the present based on lectures from prominent creationists, summer camps to teach Creation Science to children, and Creation Science museums. While the era of attempting to balance evolution with creationism may be over, the young-earth creation science view is still widely taught in the US outside of school and its proponents are still active, even if less prominent.

After 1968 several states passed laws requiring the teaching of both theories side-by-side yet these laws again were challenged in the Supreme Court. In *Edwards v. Aguillard* the Supreme Court again decided that creationism could not be taught in schools because it gave preferential treatment to one religion but further stated that alternative theories to evolution could be taught if they had a secular and scientific purpose. This decision therefore still technically left a door open for proponents of creationism to attempt to balance the teaching of evolution with some alternative.

That alternative was the theory of Intelligent Design (ID) and it has dominated the rhetoric of the creation movement in the last two decades. The theory, however strongly linked to the old creationist movement, attempts to establish its image on strictly scientific grounds and seeks to challenge science with its own tools. It took the lesson from *Edwards v. Aguillard* and molded a seemingly secular alternative to evolution. However, this also meant stripping Creation Science of most of its most Biblical arguments, such as the young earth and flood explanations. In the end, ID proponents will often agree that evolution has occurred for millions of years yet question whether biological evolutionary mechanisms alone could produce life as we know it. Often the question of whether the intelligent designer of life on earth could be other-worldly life gets asked of the Intelligent Design Theory and often its proponents are forced to concede that as a possibility. Instead of focusing on a Biblical alternative to evolutionary theory, ID's focus shifted to providing a scientific account for Creationism that also acts as a scientific alternative to Darwinian evolution. One of the central concepts of Intelligent Design was crafted by biochemist Michael Behe in his 1996 book *Darwin's Black Box* in which he put forth the theory of irreducible complexity. The theory argues that some biological structures are so complex that it would have been impossible for them to have evolved. The most often cited example of this is the bacterial flagellum due to its resemblance of a motor. If one of the parts is removed, they argue, then the flagellum ceases to function, and therefore could not have evolved as any extra addition would have added no gain until all assembled. Thus the ID movement posed another serious challenge to evolution's standing in the classroom, despite remaining a thoroughly revised version of Creationism. It is also important to note that Intelligent Design, the theory as formulated by its proponents and organizations like the Discovery Institute, did not replace Creation Science, or at least, did not replace it outside the courtroom. Instead Creation

Science and Intelligent Design mutually supported each other with Intelligent Design acting as the spokesperson for the broader Creationist movement, its secular and scientific appearance lending credibility to the movement.

Intelligent Design's day in court came in 2005, in a case involving the Dover Area School District in Pennsylvania and parents of the students at a local high school. The parents sued the School District for changing the biology curriculum to recommend an ID textbook. Now it was ID's turn to prove itself as scientific and secular. The trial was a disaster for the ID side, mostly because the plaintiffs showed that the particular book in question, *Of Pandas and People*, was actually an old Creationist textbook with the phrase Intelligent Design simply substituted for Creationism after the Edwards case. The judge for the District Court in Pennsylvania saw ID as simply a new version of Creationism, stating in his ruling that:

> The facts of this case makes it abundantly clear that the Board's ID Policy violates the Establishment Clause. In making this determination, we have addressed the seminal question of whether ID is science. We have concluded that it is not, and moreover that ID cannot uncouple itself from its creationist, and thus religious, antecedents…[148]

While the case was not adjudicated in the Supreme Court but a lower District Court, the ruling was strong enough to kill any chance for Intelligent Design to be taught in school unless something profound changes in the laws. Therefore the Dover decision may have effectively terminated the second phase of Larson's analysis in an attempt to balance evolution in the classroom. However, the third approach used by Creationism in the evolution controversy is to teach evolution as just a theory and it got its first meeting in court one year after the Dover trial.

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[148] Tammy Kitzmiller et al. v. Dover Area School District et al., 400 F. Supp. 2d 707.

Again, a school district was sued by parents after the district required that a sticker be placed in science textbooks stating that evolution was just a theory and should be approached with a critical mind. Like Dover, the judge ruled that the stickers were unconstitutional as they were promoting a religious purpose.

This ruling did not end the "just a theory" attack but is now moving it in a different direction to focus on science criticism in general. This move too, is not without precedent. First, while the history of the public controversy may be well described by the court rulings over its teaching in school, the broader cultural clash in the United States is just as important, if not more in the long run. There is a long-seated distrust of science in general among not only fundamentalists, but those in the new age movement who are often more concerned about preserving the mystery of things. In the 1960's Richard Hofstadter identified this sentiment as an anti-intellectual trend in American society, laying most of the blame on the fundamentalist movement.[149] More recently, views antagonistic to science have also led to a rejection of global warming and severe reductions in funding for certain areas such as stem cell research. This attitude is only compounded by the media structure in the US which will readily cover controversy in science while often ignoring the less shiny scientific developments.[150]

Another very relevant, and perhaps more important aspect, behind the science criticism approach to evolution is how the ideas of the history and philosophy of science are appropriated for the debate. The criticism lobbied at scientific ideas is not nearly unheard of in Creationism. While the new age movement rallied behind the postmodern criticism of science, the Creationist movement had long employed the works of earlier philosophers, namely Karl Popper and

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[149] See Richard Hofstadter, *Anti-Intellectualism in American Life*
[150] Rae Goodell, "Role of mass media in scientific controversy," in *Scientific Controversies* (Cambridge: Cambridge University Press, 1987), 587.

Thomas Kuhn. Creationist Kent Hovind repeatedly relied on Popper's notion of falsifiability to insist that Darwinian evolution was not a scientific theory because it could not be tested. Meanwhile, Philip Kitcher has pointed out how Creationists have misunderstood Kuhn by pointing to the *Structure of Scientific Revolutions* as a condemnation of the stubbornness of scientists.[151] However, the Creationist side is not completely misinterpreting the philosophers of science. While Thomas Kuhn never argued for challenges to evolutionary theory, Karl Popper and Paul Feyerabend both took the stance that alternative theories to evolution should be taught in the classroom, with Feyerabend outright supporting the creation science movement while Popper eventually reformulated his stance to acknowledge evolution's falsifiability. Popper made the original statement that "Darwinism is not a testable scientific theory but a metaphysical research program," yet was also quick to point out how it's invaluable to science.[152] In Feyerabend's conception, an alternative to evolution being taught beside it is quite appealing. In a later version of *Against Method* Feyerabend would state that, "Galileo wanted his ideas to replace the existing cosmology, but he was forbidden to work towards that aim. Today the much more modest wish of creationists to have their view taught in schools side by side with other competing views runs into laws setting up a separation of church and state."[153] If more theories compete against each other then they are better able to get closer to the truth through greater articulation. In many ways this has occurred in the Creationist movement and in evolutionary theory. With evolution challenging some deeply held fundamentalist views, they were forced to come up with plausible explanations that justify the literal interpretation of the Bible. After the Creationist challenge in the schools fell, the movement had to once more further articulate its

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[151] Philip Kitcher, *Abusing Science, The Case Against Creationism* (Cambridge: Massachusetts Institute of Technology, 1982), 168.
[152] Karl Popper, *The Unended Quest* (New York: Routledge, 1974), 195.
[153] Feyerabend, *Against Method* 4th edition (1988), 130.

views in the form of Intelligent Design, perhaps giving up some ground, like the belief in the young earth, but still retaining the core anti-Darwinian thesis. Now that Intelligent Design is withering the movement must rearticulate their belief to the level of epistemology or attacking how science tells us what we know. It has gone from Biblical literalism to deistic evolution, to a broad form of deism.

Evolutionary theory too has been forced into greater rearticulation. While scientists had reached a broad consensus on evolutionary theory, creationism still forced evolution to address some issues that would otherwise not have been addressed. An in-depth study looking at how scientists have considered and responded to Creationist challenges may reveal some careful reconsiderations of explaining evolution and possibly some new research directions but a few simple examples can provide a brief analysis on the subject. First, and most recently, the idea of irreducible complexity proposed the challenge of the bacterial flagellum and other structures. How could non-purposeful evolutionary theory create complex machine-like structures? Well, after Behe's 1996 book which examined and labeled the flagellum as irreducibly complex, biologists gave it another look. Ian Musgrave detailed the work and possible explanations for the irreducibly complex motor on bacteria. Musgrave and others concluded that the original purpose of the flagellum was most likely secretory, used to pass proteins through a membrane.[154] Furthermore, they noted the large variety of flagella and similar structures being used for different purposes, so while one component of the motor, if removed, would stop the motor from being a motor, it could still be used in some other way. Through introducing the bacterial flagellum as an example, Behe inadvertently directed a research program to solve the puzzle.

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[154] See Ian Musgrave, "Evolution of the Bacterial Flagellum," in *Why Intelligent Deisgn Fails* ed. Matt Young and Taner Edis (New Brunswick: Rutgers State University, 2006): 72-84.

A second example comes from a controversy in evolutionary theory itself, and previously mentioned in this paper, the theory of punctuated equilibrium. When Gould and Eldredge proposed the theory in 1972 they were partly responding to a common creation science criticism that the fossil record was full of gaps. The editorial introduction to their paper, "Punctuated Equilibria: An Alternative to Phyletic Gradualism," begins with a series of sarcastic but meaningful quotation marks. From the second sentence of the introduction, the tone is set,

> But the significance of "gaps" in the fossil record has been a recurrent "difficulty," used on one hand to show that spontaneous generation is a "fact," and on the other hand to show the "incompleteness" of the fossil record. Some have expressed a third interpretation, which views the gaps as the logical and expected result of the allopatric model of speciation.[155]

Eldredge and Gould themselves however, spend just as much time worrying about the acceptance of what they and many others considered a new and breakthrough theory. While their paper serves to counter a creationist argument, the authors at the same time draw inspiration from Paul Feyerabend when they claim that "all observation is colored by theory and expectation."[156] Eldredge and Gould certainly see their work as revolutionary and against established thinking, yet others have argued that their theory is simply a reinterpretation of axioms already present in Darwinism. Michael Ruse, a philosopher of science much-involved in the public evolution debate, contends that it is wrong to see punctuated equilibrium as simply a "wrinkle" in evolutionary thought.[157] He argues that within the evolutionary community it did

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[155] Niles Eldredge and Stephen Jay Gould, "Punctuated Equilibrium: An Alternative to Phyletic Gradualism," in *Models in* Paleobiology ed. Schopf and J.M Thomas (San Francisco: Freeman, Cooper and Co., 1972), 82.
[156] Id., 85.
[157] Michael Ruse, "The Theory of Punctuated Equilibrium: Taking Apart a Controversy," in *Scientific Controversies* ed. Peter Machamer, Marcello Pera, and Aristides Baltas (Oxford; Oxford University Press, 2000),239.

not matter nearly as much as it did outside the community. This reaction may easily be explained by the fact that the theory was ultimately addressing a public issue of controversy, namely the fossil record. Creationist proponents even quickly dramatized the controversy of punctuated equilibrium and drew on statements by Gould as a testament to the weakness of Darwinism.[158] They took Gould's theory not as an explanation of the fossil record, but an outright admission that the fossil record was full of "gaps." Gould himself was notorious for responding quite forcefully to such misquotations of his work, stating, "It is infuriating to be quoted again and again by creationists—whether through design or stupidity, I do not know—as admitting that the fossil record includes no transitional forms."[159] Through the interest outside the scientific community, punctuated equilibrium became controversial within the broader community.

These challenges shows that while it is widely acknowledged that scientific areas of research follow funding or practical application, they may also arise from non-scientific public challenges. Both creationist and evolutionary theories have evolved through competition with one another and been rearticulated through such competition in a Feyerabendian fashion. While Feyerabend's specific endorsement of creationism in the classroom may appear as an idealistic libertarian attitude towards education, Creationist theory has helped progress evolutionary theory to some extent. However, it is also important to note that the creationist challenge has also had negative impacts on the progression of evolution theory, although they are much more difficult to show, encountering the same problems as counterfactual history. Trying to measure the negative impact may look at how much the scientific pool of talent has withered simply from less competition. If half of schoolchildren refuse to accept evolutionary theory then it potentially

[158]One example: http://creation.com/that-quoteabout-the-missing-transitional-fossils#txtRef5
[159] Stephen Jay Gould, "Evolution as Fact and Theory," *Discover* 2 (May 1981), 36.

reduces the chances for innovative talent within the field as well as decreasing the competition between future scientists. In other words, Feyerabendian competition cuts both ways, theories are better articulated when forced to compete with alternatives, yet scientists also further articulate and innovate theories in competition with each other.

Creationism's link to the philosophy of science does not simply begin and end with Popper's concern with falsifiability and Feyerabend's idealistic anarchism yet has a much more intimate relationship. Philosophers of science appear on both sides of the public evolutionary debate. The paper has already referenced Michael Ruse, a prominent pro-evolution philosopher of science who actively debates creationist and ID proponents. On the other side, the popular, or once popular, creationist Kent Hovind, relied heavily on Popper, Kuhn, and others to argue for the unscientific nature of evolution. Other philosophers of science and creation proponents claim to follow in the Feyerabend tradition of a libertarian approach to public education. These arguments state that either evolution does not live up to the standards of science, or that ID does. Steve Fuller was one such philosopher who argued for ID during the Kitzmiller trial in which he testified to the scientific stature of ID. Furthermore, one of the driving forces behind the ID movement and the Dover challenge was a Seattle think tank called the Discovery Institute. Their most noted and public member, Stephen Meyer, is also a trained philosopher of science, and sought to demarcate ID as science before his institute withdrew its support from the Dover trial. When evolution may not legally be attacked, the philosophy of science provides an easy route to criticize the nature of science. It is the difference between philosophy being the watchdogs for science and the watchdogs of science. In the case of evolution, philosophy of science has often been used as a check against science rather than a commentary on science or a truthful appraisal of philosophical inquiries.

The philosophy of science trend in creationism is now culminating in the latest attack on evolution because it is the last thing surviving (as Popper would say) in the creationist argument. Philosophy of science, while not generally generating a better appreciation for creationism, does generate a greater skepticism of science. This other side in the philosophy of science, focusing on the social construction of knowledge, and culminating in the Science Wars of the 1990's and saw the ultimate withering of postmodern studies. Creationist appropriations from the philosophy of science take on a skepticism more rooted in epistemology and a criticism of philosophical materialism and methodological naturalism, or the view that science should only be restricted to the natural world. Their argument focuses on the overall purpose of science rather than how to best interpret the theories it proposes. This latest push brings the narrative of the public evolution controversy to its present state, but what does it say about the evolution of the controversy and Planck's Principle?

As mentioned earlier, the battle over public acceptance of evolution has been a rather slow process in the US with a majority of the population rejecting the theory in favor of some form of human creationism.[160] Polling data on the public acceptance of evolution is scant before the 1980's, partly because public opinion polls were not as popular and partly because it was seen as strictly an issue left to public servants and the courts. The 1980s marked the first time that Creationism was legally under attack and began disappearing from classrooms and curricula making public polls more relevant as an issue of public education policy. Eric Plutzer and Michael Berkman explored several different polls from the 1980's to the mid-2000's in their 2008 work in *Public Opinion Quarterly*. While their article is entitled "Trends," the study focuses more on drawing conclusions from the 20 years of data about attitudes towards evolution

[160] Miller, 765.

rather than a change in belief. However they do find some interesting things. For instance, when given the choice between only "Darwinian evolution" and "Biblical account" evolution received its lowest amount of support at about 25 percent.[161] This result may be explained by the alignments of people in the wider array of evolutionary beliefs. When people are asked to what degree they agree with a statement like "human origins are best explained by evolution from other species" a small group, generally around 15 percent will be in complete agreement while a much larger group, between 30-40 percent will completely disagree.[162] Similarly, when the question is posed in terms of different degrees of theistic evolution, a small percentage, this time around 10 percent accepts unguided natural selection, a much larger group, averaging around 45 percent, believes in young earth creationism.[163] While there is an attitude of certainty on both sides, it certainly resonates stronger on the creationist side with a majority of those supporting creationist views completely disagreeing with evolutionary theory. Most of those that adhere to some form of theistic creation comprise the vast majority of the American populace and therefore it also comes as no surprise that the vast majority also favor teaching creationism, either alongside evolution or on its own.[164]

While the Plutzer and Berkman article draws from a variety of polls, many are too limited or inconsistent in their questioning to draw trends from. The most consistent, relevantly worded, and thorough polls have been conducted by Gallup from 1982 until the present. Gallup summarizes their poll with the question and graph below:

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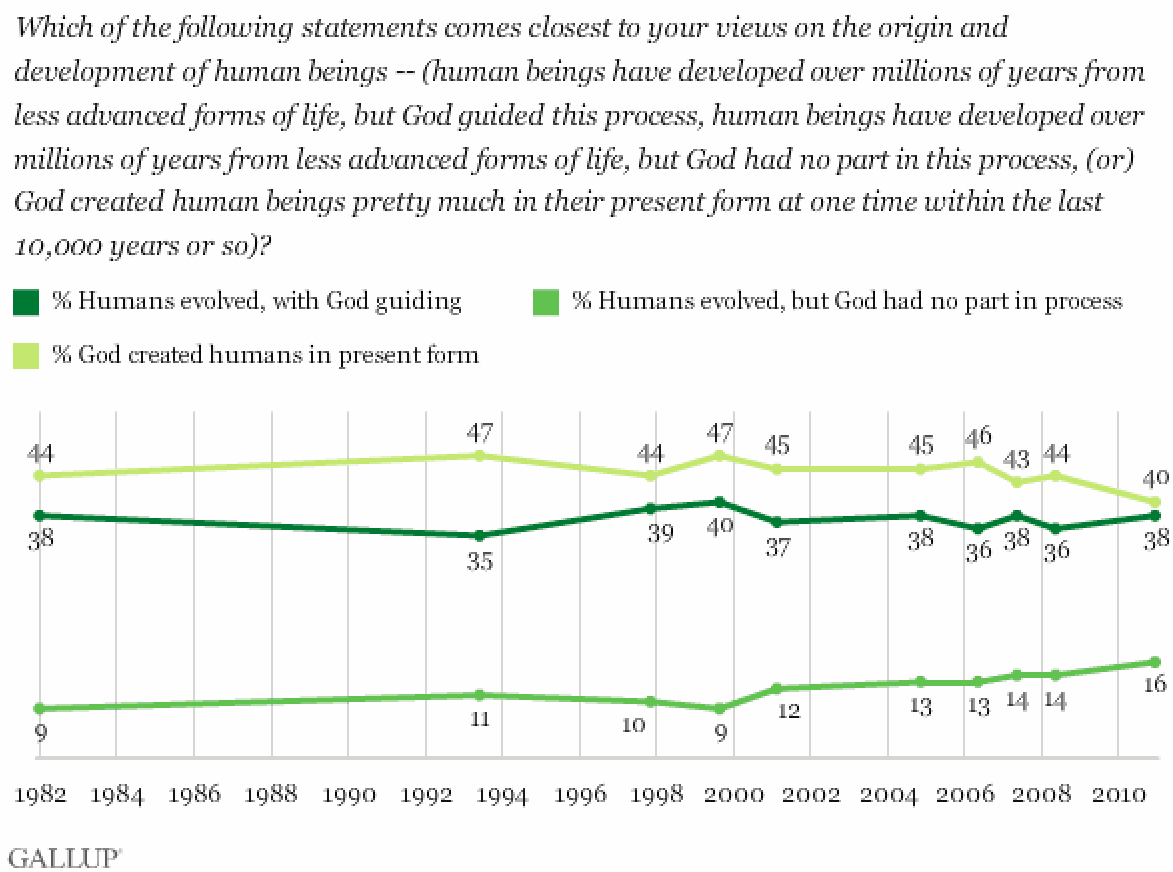
[161] Eric Plutzer and Michael Berkman, "Evolution, Creationism, and the Teaching of Human Origins in School," *Public Opinion Quarterly* 72 no. 3 (Fall 2008), 547. 540-553
[162] Id., 543.
[163] Id., 545.
[164] Id., 551.



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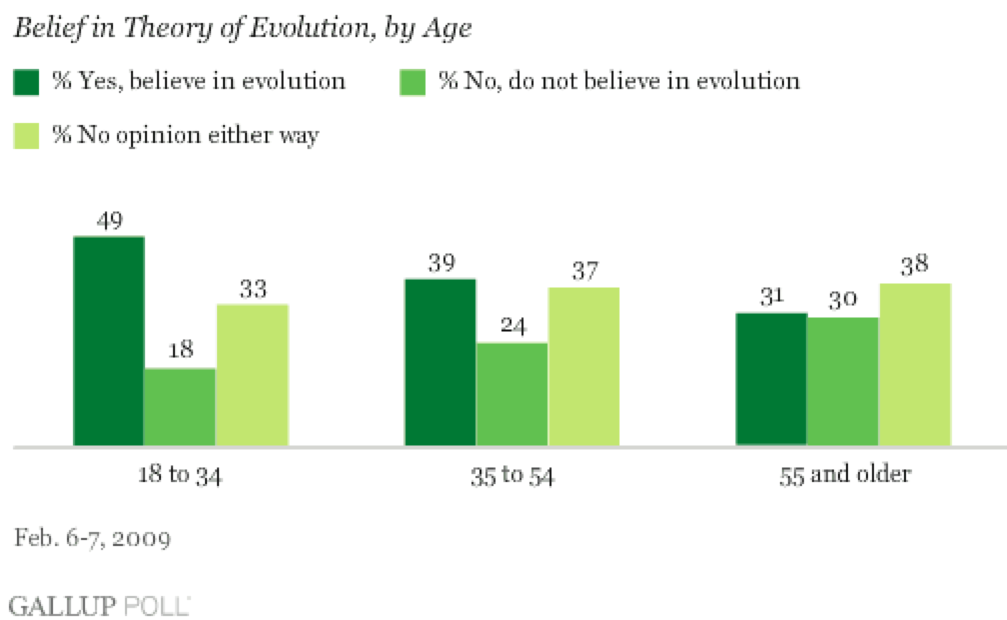
Since 1982, the polls show a trend of an increase in non-theistic evolution and a decrease of young earth creationism, with theistic evolution more or less remaining steady. Are we to interpret this as the effect of the first anti-creationist rulings in school? First, I think it's necessary to caution that these polls may be based more on religious views than adherence to a scientific theory, although in the case of evolution they are often hard to part. Creationists may be correct in their argument that teaching evolution does lead to atheism to some degree. One could also purely speculate that the rise in acceptance of unguided evolution after 2000 was caused by an educational lag from the Edwards decision in 1987 as all participants in the polls were over 18. A Gallup 2009 poll which posed the standard question above as well as others,

[165] "Evolution, Creationism, and Intelligent Design," Gallup: http://www.gallup.com/poll/21814/Evolution-Creationism-Intelligent-Design.aspx.

found clear trends with education[166] but it would be interesting to sample only those with high school education and belief in evolution since the Edwards decision and specifically in states where creationism was removed from the curriculum. Unfortunately the data remains to be collected, although I imagine that it has already been thoroughly examined by Intelligent Design think tanks. However, another curious find from the 2009 poll partly confirms a reason for the trend since 1982. When the data was broken down by age another trend emerges, one that shows that younger people are much more likely to accept unguided evolution than the older generation.[167]



Previous Gallop polls have analyzed age differences with similar trends[168] yet the earlier polls don't give the "no opinion" option and have a different and perhaps more misleading age

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[166] Frank Newport, "On Darwin's Birthday, Only 4 in 10 Believe in Evolution," Gallup, (Feb. 11, 2009), http://www.gallup.com/poll/114544/Darwin-Birthday-Believe-Evolution.aspx
[167] Id.
[168] Frank Newport, "American Beliefs: Evolution vs. Bible's Explanation of Human Origins," Gallup, (Mar. 8, 2006) http://www.gallup.com/poll/21811/American-Beliefs-Evolution-vs-Bibles-Explanation-Human-Origins.aspx

range breakdown.[169] This result is not surprising as any trend in polling over years should reflect the age breakdown of any one year. It essentially becomes a restatement of Planck's Principle. Not that an older person is less likely to accept a new theory, but that no one is likely to accept a new theory, a person accepts a theory because they grow up with it. The gradual trend represents a public shift, not based on a campaign to convince the public or appeal through debates, but one through passage of time, through new people accepting less new ideas. The evident nature involved in Planck's Principle drives the challenge over evolution in the schools, people want to teach their children a certain way, especially when public funds are involved. It's also the same reason why marketers try to reach their audience young to develop brand loyalty.

The new scientific truth may be interpreted by both the scientific community and the public on different grounds and for different purposes, but through methodological anarchism progress may be achieved in both. But does this then mean that creationism was and still is the public scientific truth based on its acceptance in the population? The answer should be somewhat, in the sense that Feyerabend would say yes and Planck would yell no. The courts in the US have effectively ruled what science is regarding evolution yet in the public mind a consensus has still not been reached. Another recent poll shows that only 51 percent of Americans believe that scientists generally agree on evolution.[170] Therefore, it seems that a public scientific controversy will only end when the public recognizes a scientific consensus. If the public believes there is a consensus then anything outside that perceived consensus is non-scientific.

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[169] The earlier polls generally have the first age category from 18-29 and only ask about creationism. I say this may be more misleading because given the clear trend between levels of education and acceptance of evolution, the 18-29 group may be underrepresented in the category while the next age range might be padded with fresh post-grads. Another reason to further analyze those with only high school education.

[170] "Survery: Climate Change and Evolution in the 2012 Elections," Public Religion Research Institute (Sept. 22, 2011) http://publicreligion.org/research/2011/09/climate-change-evolution-2012/

Victorian England at the turn of the twentieth century provides another example. Society, ever-curious from a global empire had begun embracing spiritualism and occultism. Prominent intellectuals such as Carl Jung and Sigmund Freud attended séances and investigated the phenomena of ghosts and supernatural occurrences. Eventually Britain established the Society for Psychical Research to investigate the situation and after years of careful study concluded that there was nothing supernatural or otherworldly happening. While British society did not outright reject spiritualist explanations, they did recognize the scientific consensus reached by the Society. Presently there are no movements to teach ghost theories in school, although many American fundamentalists do petition schools to boycott Halloween.

Thus the Discovery Institute's now infamous "Wedge" document, which provides an outline for the ultimate acceptance of design theory and religious revival, serves as a plan to break the consensus in science on evolution. The wedge is a push to first get intelligent design accepted into academia and establish research programs and eventually to have ID as the dominant one.[171] Unfortunately for the Discovery Institute the Wedge was drafted long before the ruling against ID in the Dover trial and none of their goals achieved much success. Now only evolution, and no non-scientific, non-secular alternatives may be taught in schools; those growing up, while perhaps not ascribing to the theory, will learn it as science, as the scientific consensus. This new development also explains the new creationist response of science criticism; if evolution has a consensus, then the power of consensus should be undermined. Kuhnian notions of normal and revolutionary science have been compared to punctuated equilibrium. A scientific community is thrown into chaos and an altogether new paradigm emerges from an old. Yet, perhaps, as with the criticism of Eldredge and Gould, Kuhn is

[171] "The Wedge," The Discovery Institute, 1999.

overemphasizing the features of an evolutionary system already present. While a scientific community's acceptance of any given theory may alternate between periods of stasis and fluctuation, the public exhibits a much more gradual shift in opinion. This gradualism is consistent with the humanity epitomized in Planck's comment, one borne out of emotion and frustration and leveled against other's exhibition of stubborn emotion unchecked by professionalism. The word allmählich again springs to mind with its alternative translation of "gradually."

The public evolutionary controversy is one of gradualism, both in the strategies employed over children's education, and in its historical character of public resistance. While Hull et al have showed how a Darwinian revolution actually occurred quite quickly in Britain the decade after *Origin* was published, the public's acceptance of the theory has been long and protracted, even fluctuating at times. The evolution of this public controversy also comes in generational waves brought about by periods of stasis and fluctuation. These periods are not brought about by revolutionary change but by an ongoing public dialogue with two sides countering each other's arguments, competing, and coevolving. The battle over evolution in the US has largely been fought in the courts with the creationist movement evolving to meet the selective pressures by the courts, in this case those set through the demarcation of science and religion. With every court ruling a new tactic is employed and a new defense prepared from evolutionists. Thus the history of evolution and creationism controversy becomes a prime example of generational change within the legal challenges. Each new ruling brings a change of proponents and the trend shows that soon the next generation of philosophers of science will play a prominent role in shaping the controversy and the public curricula.

12. Conclusion: The Place of Evolutionary Metaphors in the Philosophy of Science

Science does have an evolutionary character in that it changes over time through competition between theories. Trying to apply biological mechanisms like random variation or notions like punctuated equilibrium will often encounter trouble among the details. Luckily evolutionary theory is predicated on similar historical and competitive concepts that allows for a certain usefulness of appropriating evolutionary metaphors to scientific frameworks. It finds its use first and foremost through science's human and historical nature. The philosopher, Norwood Russell Hanson, drawing inspiration from Kant, once wrote that "history of science without philosophy of science is blind…philosophy of science without history of science is empty."[172] Scholars have not always agreed with this statement and through the years there have been vociferous arguments from the extremes of both sides – philosophers of science disregarding history for epistemology and historians of science disregarding philosophy because of its most banal and unpractical aspects. However, without history, philosophy of science is not merely empty but without any fossil evidence at all.

Charles Darwin studied geology before setting off on the infamous voyage of the Beagle, knew about fossils and noted several large fossil finds throughout the journey. Much of the work in *Origin* details the geological record and Darwin's interpretation of it. If Darwin knew nothing of fossils would he still have arrived at his theory? The Malthusian theory of resource competition did not rely on fossils so why must Darwin's? But maybe, and more importantly, we can ask what if evolutionary theory had no fossil evidence to rely on, not the "no fossil evidence" argument employed by creationists, but simply no access to fossils to look back and reconstruct previous forms of life? The theory would become more than simply empty, it would

[172] Hanson, 580. Kant's statement was "Thoughts without content are empty, intuitions without concepts are blind."

become non-existent; it would fail to survive. Furthermore, does history of science merely provide evidence to corroborate the philosophy of science or are historians like the paleontologists in the punctuated equilibrium debate concerned with the pattern left by the past? Here L. Pearce Williams has made the argument that the history of science actually fails philosophy due to the lack of examples.[173] Science simply doesn't have enough fossils to justify philosophy.

The philosophies of Planck, Kuhn, Popper, and Feyerabend all represent appropriations of an evolutionary metaphor for their own needs, emphasizing rigidity, transformation, survival, and competition respectively. These aspects provide the framework for a scientific structure (or non-structure) as an evolving one and if science has evolved then from what? And then does science share a common ancestor with all other disciplines, do concepts and language have a common ancestor? Following these questions will eventually lead to evolutionary epistemology and sociobiology. Rather science as an evolving enterprise becomes useful through its appeal to not so much the changing views of a scientific community, but a changing scientific community itself and the natural shifting of roles and responsibilities in the community with age. New scientific truths are born through authority, consensus, indoctrination, or whatever else one might call it. These truths are solidified by both their inclusion in textbooks and through their transference through such books to the next generation. Histories based on Planck's Principle would focus on education as a means of closure, public or external resistance, and population shifts over time between proponents and opponents. Its implications are naturally long-term, partly due to economic restraints on communication and costly revisions, partly due to natural human resistance, and partly due to the pace of science. Consider the slow evolution of the

[173] Williams, 50.

Quantum Mechanics interpretation controversy. Certainly not as prominent as it was in the early 20th century, physicists are still arguing over which interpretation still holds water. The Copenhagen theory, once the dominant theory under the leadership of Neils Bohr, has had its support gradually eroded by other interpretations but namely Everett's 1957 "Many-worlds" interpretation.

So how are we to make sense of what an evolutionary theory of science offers philosophy? Speculating and sticking with biological analogies, ideas may be akin to stem cells where there is a sort of innate intelligence about how the world works, perhaps even in the vein of Campbell's nested heirarchy. It is only through greater articulation, literalization, or description of such ideas that theories are formed. Thus the idea exhibits a certain flavor through a more thorough and nuanced description. It is this reason that political or philosophical arguments prove so inconclusive, as when all nuances and intricasies are stripped away, a broad unarticulated middle-ground remains that is taken for granted. Two people at the core may share the same sentiment but find themselves far apart on the actual issue. However, there are more than assumptions that remain behind with all articulation removed; assumptions too may be overturned. These ideas are innate, the same way that the ground will always be the foundation regardless of what is built upon it. The human mind will always be the foundation for ideas and billions of years of evolution has imprinted an architecture of invaluable intelligence in the human organism. It is akin to Chomskyan linguistics which argues for a common liguistic architecture. And so, if Chomsky's theory is correct, it is this architecture which perhaps shapes, or even limits, intelligence as well.

There are essentially three types of theories of scientific progress, cumulative, revolutionary, and evolutionary. Cumulative is seriously flawed – people die. However, if history preserves the record well enough could keep a sufficient record of ideas, it may be cumulative in the sense that all former ideas are still accessible. L. Pearce Williams would disagree. We seem to have the idea that anything people have done in the past we can do now yet time and again we have been proven wrong. Upon the centennial of the Wright brothers' famous first flight, historians and engineers attempted to reconstruct a working replica of their plane. Unfortunately they found that even with a relatively recent technology, they still lacked the tacit knowledge needed to operate the machine.[174] Saying science is cumulative is like saying architecture is cumulative, we may see vestiges of architectural examples here and there but buildings come and go and a city's architecture will change over time. Kuhn's revolutionary conception, upon close analysis is really just a matter of perspective within an evolutionary conception. Kuhn even refers to science as an evolving enterprise in SSR. Science is occasionally revolutionary, where a complete break from the past occurs, such as the Copernican Revolution, but depending on how long the transition takes it may be hard to consider these revolutions as opposed to evolutions. Or if a change in theories occurs quite quickly, such as in the Darwinian Revolution, closer analysis may reveal that Darwin's theory was not a complete break from the past, but just a theory with better problem-solving ability. I think we can safely say that given these choices, science evolves. Yet this is where the connotation of evolution itself just breaks down to the point of ambiguity. Progress, even as Feyerabend conceives it, is often used synonymously with evolution. In a progression things follow each other bit-by-bit in a determined and meaningful way. Evolutionary theories of scientific progress must take on a Lamarckian or teleological character, even while retaining aspects of competition and external pressures. Planck's Principle as a framework for evolutionary theories of science avoids the

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[174] Tom Incantalupo, "The Wrong Stuff, Nation Marks Wright Centennial Despite Failed Re-enactment," *Newsday*, 18 Dec. 2003.

pitfalls of other conceptions because it explicitly avoids this teleology. Science is what it is. Planck may not agree, but a scientific truth is defined by the community at the present. This is the most natural explanation of science; scientific truths will never exist in spirit, but always appeal to scientists and it will always be the historian and philosopher's job to catalog and examine these current and past truths.

Planck's Principle in the philosophy of science may best be compared to (what I promise is the last evolution analogy of the paper), Herbert Specer's phrase "survival of the fittest." Spencer coined the term after reading Darwin's work and it is now rampant in the vernacular. "Survival of the fittest," ultimately, like Planck's Principle says almost nothing if taken as its most literal truism. The fittest are the ones that survive by definition. However, upon closer inspection and reflection within the context of competition with other theories of evolution, "survival of the fittest" affirms that evolution is not teleological; given the implicit teleological assumption, by saying nothing it says something. Rather it hints that each examination should be done on a case by case basis, and fitness may only be determined in retrospect given a particular species or mechanism. However, just like Planck, Spencer too has been misinterpreted. The Gallup polls showed that most people believe in some form of teleological evolution and this is reflected in the interpretation of the phrase. Often students and the public will latch on to the modern connotation of fitness which encompasses meanings like health and athleticism rather than reproductive success. This misinterpretation presents a normative interpretation of "survival of the fittest," whereas the original intent of the phrase represents a break from the teleologically-laden past theories. Planck's Principle serves the same purpose. It removes the teleology of Popper's structure of falsification and even the quasi-teleology of Kuhnian problem-solving. Instead, it falls into the Feyerabend's "anything goes" approach to science, which may be no surprise as Feyerabend was another who also managed to say a lot about the structure of scientific methodology by saying nothing.

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