The Other Side of the Dark Side:

Underdetermination and Unconceived Alternatives In Science

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Abstract:

Arguments from underdetermination take two forms, those from global sceptical underdetermination, global scientific underdetermination and local underdetermination. Arguments from global sceptical underdetermination bring into question all knowledge, they develop sceptical scenarios that purport to show that we cannot trust any ‘knowledge’ that we obtain within the world. Arguments from local underdetermination aim to bring into question the nature of our knowledge and are geared against scientific realism. This thesis is an evaluation of the arguments that claim to do the latter, however it shows that these arguments are not arguments from local underdetermination but are from a type of global underdetermination that I call global scientific underdetermination. Based on this evaluation a new argument from local underdetermination is developed that attempts to show that nevertheless local underdetermination is indeed a problem for scientific realism. However, I argue that this argument also fails to undermine scientific realism. Recently Kyle Stanford has reintroduced an historical argument from underdetermination that he calls the argument from unconceived alternatives. Stanford’s argument from unconceived alternatives is an inductive historical argument. It maintains that scientific theories are chosen from a non-exhaustive set of theories; claiming there is always at least one unconceived alternative that would better explain the empirical evidence. Stanford’s new induction attempts to undermine scientific realism by arguing that our most successful theories will eventually be shown to be false. Various arguments against this induction will be considered. It will be shown that traditional scientific realism fails to address the argument from unconceived alternatives and the only form of scientific realism that can overcome this problem is structural realism.

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Dedication:

This work is dedicated to my parents Jacqueline and Bill Sawkins for all the love and support that they have given me throughout my academic career.

Table of Contents

Introduction:

Scientific realism is the epistemological thesis that we know that our current most successful scientific theories are true or at least approximately true. The criteria for a true theory, according to scientific realism, are that it is successful in its predictions and descriptions of reality. Conversely, scientific antirealism maintains that we can never know that a scientific theory is approximately true. An obvious question arises from this denial: what then does science do if it does not get at the truth? There are many different answers to this question given by scientific antirealists. The pragmatist for example explains that a central goal of science is usefulness, for a scientific theory to be successful it must be useful. To be useful a scientific theory must make some useful predictions or be applicable to technological advancements. In order to argue against the scientific realist, the antirealist employs two lines of reasoning that support her position and cast doubt on the scientific realists' claim that we can know when our scientific theories are approximately true. The main goal of the antirealist then is to show that we do not know that certain elements of our theories are true. To do this some antirealists utilize the history of science to show that successful theories of the past which were once held to be true are in fact false and thus since those theories are in fact false, our current most successful theories are as well. This argumentative approach is called the pessimistic induction since it is an inductive argument developed from the history of philosophy and is applicable to all our most successful theories. Another type of historical argument is called the argument from unconceived alternatives, this argument maintains that not only does the history of science show that our scientific theories are false, but they are also in a constant state of underdetermination, empirical equivalence, with at least one current unconceived alternative theory that has yet to be developed. Another approach utilizes case studies or theories generated by philosophers to show that our current most successful theories are not true because other theories exist or can easily be developed that are just as empirically well confirmed as those theories we hold to be true. The theories utilized in these case studies are underdetermined and thus this argumentative approach is called the antirealist argument from underdetermination. For two or more theories to be underdetermined they must be empirically equivalent. That is to say they must be supported by the same empirical evidence and thus are empirically equivalent.

According to the current philosophical literature there are two types of antirealist arguments from underdetermination, global underdetermination and local underdetermination.[1] The goal of global underdetermination is to call into question all knowledge; an example of this type of underdetermination is the Cartesian Demon argument according to which "some malicious demon of the utmost power and cunning has employed all his energies in order to deceive [us]…external things are merely delusions of dreams which he has devised to ensnare [our] judgments" (Descartes, 1996,

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[1] I will later distinguish between two types of global underdetermination, global sceptical underdetermination and global scientific underdetermination.

15). The underdetermination arises when we compare this thesis, which tells us that we are being deceived, to the commonsensical thesis that the world exists as our perceptions tell us it does. No amount of evidence will ever allow us to distinguish between the thesis of deception and the thesis of correct perception. Any evidence found to verify one of these theses will just as easily verify the other. The empirical evidence that makes me believe that I am sitting in my office right now, the sight of my computer in front of me, the feeling of my backrest against my back, the feel of the keyboard under my fingers, the sound of other graduate students in the hall, corroborates the claim that I am actually sitting in my office and thus corroborates the thesis of correct perception, but it does not block the sceptical move outlined within the thesis of deception. The Cartesian sceptic can just as easily explain that the malicious demon is giving me all the sensations that make me believe I am in my office. No matter how much evidence I provide towards the claim that I am in my office right now, that the world actually does exist, I will never be able to conclusively show that I do indeed exist in the real world rather than in some illusory world created by the Cartesian demon; thus, since no amount of evidence will ever be able to distinguish between the real world and the world created by the Cartesian demon, these two theses are said to be globally underdetermined. Due to the sceptical nature of these types of scenarios and the scope of the argument's scepticism, I have deemed this type of argument a case of global sceptical underdetermination. It is argued that if these arguments show that we cannot rely upon our everyday experience and thus all knowledge fails, then we know that our current most successful theories are false.

The second type of underdetermination discussed in the philosophical literature, local underdetermination, calls into question scientific knowledge. More specifically it is a direct challenge against scientific realism. This type of underdetermination claims that we cannot know that our current most successful theories are true, for an alternative theory exists or can be developed that is empirically equivalent to each of our most successful scientific theories. According to these arguments, given these two or more underdetermined theories, there are no truth-indicating reasons to guide our choice between two theories which have the same supporting evidence. An example of this type of underdetermination comes from the debate between Leibniz and Newton concerning absolute space. From Newtonian mechanics we can generate a different but empirically equivalent theory, that is, one that makes the same predictions and describes all the same phenomena, observable events, in the universe in the same manner. The only difference in the second theory is that according to it the universe is in motion relative to absolute space, while Newtonian theory says that the universe is at rest relative to absolute space. No amount of empirical data can distinguish between these two distinct theories, thus they are underdetermined by any available evidence. I will argue that, following Stanford, the current philosophical literature that develops antirealist arguments from local underdetermination generates empirically equivalent theories that are in principle indistinguishable. As a result these arguments are not arguments from local underdetermination, but from global underdetermination. Since theories that are not in principle empirically distinguishable are globally underdetermined it follows that for two or more theories to be locally underdetermined they must be empirically distinguishable in principle. This means that locally underdetermined theories are empirically equivalent, but given enough empirical evidence the theories can eventually be distinguished; they are empirically equivalent based on the amount of empirical evidence available at the time.

One approach within the literature that attempts to develop an argument from local underdetermination examines cases of empirical equivalence in contemporary science. However, it will be shown that even this approach has failed for the case studies examined are cases of global underdetermination rather than local underdetermination. [2] In order to make the antirealist argument from underdetermination as strong as possible, I will develop a new argument from local underdetermination that I call the new general argument which effectively challenges scientific realism. Once this new argument is constructed, I will provide a means of rectifying scientific realism from this argument. This will effectively show that scientific realism is correct, that we can know when our scientific theories are true.

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[2] In order to distinguish between global sceptical underdetermination that questions all knowledge and this type of global underdetermination that focuses only on scientific knowledge, we will refer to the latter type as global scientific underdetermination.

Chapter 1: Determining Underdetermination

1.1 Assessing the Threat: Underdetermination in the literature

Global Underdetermination

Within the philosophical literature there are two types of underdetermination utilized in producing arguments from underdetermination, global underdetermination and local underdetermination. As was discussed above, an example of global sceptical underdetermination is the Cartesian demon argument, “where there might be an all powerful ‘Evil Demon’ who devotes all his energies to deceiving us about what the world is really like” (Stanford, 12). No amount of evidence can distinguish between a world controlled by the Evil Demon and one that is not. Another example of global underdetermination is presented by the dream argument, in which Descartes discusses the differences between experiences while dreaming versus experiences while awake; he states that “there are never any sure signs by means of which being awake can be distinguished from being asleep” (1996, p. 13). If one day I were to fall asleep and have a vivid and complex dream, one which begins with my waking up from falling asleep I would never be able to distinguish between my waking life and my dream life. I would never be able to find enough evidence in my dream life to ascertain that I was in fact dreaming. Arguments from global underdetermination, then, are sceptical in nature as they bring into question both our possession of any knowledge and the nature of what we perceive to be the real world is brought into question.

Even if the examples of global underdetermination are correct, we can still proceed with academic and scientific enquiry. For even if the world is a construct within a computer program into which we are plugged, or a figment of a demonic imagination, it is the world within which we ‘reside’ and as such we can make empirical observations about that world that allow us to function within it and better understand it. We can make predictions of what will ‘happen’ in the world. The claim that we live in a computer or demon controlled world does not negate the knowledge that we have of that world, whether it is simulated or real. Our knowledge allows us to manipulate the world that we live in, whether by curing diseases, creating technology or other advancements. Thus, even if the world that we live in is a simulated world, it is clear that our scientific theories can be at least approximately true. This idea stems from Rudolf Carnap’s philosophical position on linguistics and abstract entities, discussed in his paper “Empiricism, Semantics, and Ontology”. Carnap argues that we can understand abstract entities, such as numbers, from within the framework established by our use of the language and the theories of these abstract numbers. Thus we can talk about abstract entities from within the framework, asking questions that are internal to the framework, even though from within a framework we cannot ask question about the framework, “questions concerning the existence or reality of the system of entities as a whole, called external questions” (20). Similarly, I am suggesting that in the face of global scepticism bnwe can ask internal questions. Internal questions lead to knowledge about the world from within the framework, i.e. from within the world, regardless of whether the world is demon created or as we believe it to be and we can ask external questions about the world itself, i.e. sceptical questions about the reality of the world[3]. Asking external questions about the underlying reality as the Cartesian demon argument does not undermine our knowledge established from within the system it only casts doubt on its status of knowledge.

Furthermore, it seems we can cast doubt on the creativity of the programmer of the computer simulated world, or the demon, for the creator of the simulation would base the physical laws of the simulated world on his real world rather than generating a world that operates on completely different physical laws. The imagination of the creator would be limited by her knowledge and since her knowledge is based on the world in which she lives, thus our world, the simulated world, would be similar to her world. Thus, the knowledge that we can obtain in the system of the simulation can be applied to the real world, the world of the programmer or the demon. If a person were to somehow escape the simulated world and enter the real world, it seems unlikely that they would not be able to function in the real world. The knowledge that this person had obtained in the simulated world would be applicable to the real world, for the simulated world would in some way have to be based on the real world. Furthermore, the simulated world would have to be compatible with the physiology of the captive's brain. It would be a world that could be experienced through the five senses since the brain is hard wired to interpret the stimuli that is received through our sense receptors. Thus, the possible nature of the

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[3] The distinction between external and internal questions is the only element which I wish to draw from Carnap's discussion.

simulated world would be restricted by our physiology and the imagination of the creator of that world.

Even if the creator of the simulation is somehow able to construct a world that is fundamentally different than the real world, the knowledge that we obtain in the simulation works within the constructed world. Thus, arguments from global underdetermination do not bring into question our scientific knowledge if we consider our knowledge within the system itself[4]. We have knowledge if we consider the closed system only. The second type of underdetermination, local underdetermination seeks to undermine scientific realism. More specifically the argument from local underdetermination seeks to undermine the philosophical position of scientific realism. The terms global and local refer to the extent that our knowledge claims are challenged. The term local indicates that only our scientific knowledge claims are challenged. The term global indicates that all our knowledge claims are challenged. Furthermore, cases of local underdetermination can eventually be resolved, whereas global underdetermination cannot be resolved. Thus an antirealist argument from local underdetermination ought to utilize genuine scientific cases where two or more theories are underdetermined such that they can eventually be resolved. Furthermore, such an argument ought to show why local underdetermination is a potential problem for scientific realism, the philosophical position that states that we can know that our most successful theories are approximately true.

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[4] Assuming there are no other problems with the way we generate scientific beliefs.

Local Underdetermination

Within the contemporary philosophical literature that develops the argument from underdetermination, there are three strategies for producing a general argument from what the authors perceive as local underdetermination.[5] The three strategies are the algorithmic approach, the pessimistic induction approach and lastly an approach that utilizes case studies of underdetermination in science. These strategies will be considered in full and it will be shown that they are insufficient in producing a strong general argument from local underdetermination. The algorithmic approach fails to produce a general argument from local underdetermination; it merely instead reformulates the sceptical arguments of global underdetermination. The pessimistic induction approach produces a strong anti-realist argument; however it is an argument that focuses on the falsification of past theories and not underdetermination. The approach that utilizes case studies of underdetermination in science to produce a general argument looks most promising; however the contemporary literature either utilizes cases of global underdetermination or uses historical cases which only serve to produce inductive arguments. The goal of this chapter then is to evaluate each strategy of producing an argument from local underdetermination. It will be shown that each strategy fails to produce and to constitute an argument from local underdetermination, but instead produces a type of global underdetermination that I call global scientific

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[5] See Earman 1993, Psillos 2009 and Stanford 2006.

underdetermination. Based on this evaluation I construct a new argument from local underdetermination from the most promising strategy. I then show that underdetermination is a problem for scientific realism, because given empirically equivalent theories we cannot know which theory is true or even approximately true.

The Algorithmic Approach

The algorithmic approach has been developed to produce alternatives to our most successful theories. These algorithms allegedly allow philosophers to generate an empirically equivalent theory to any theory at all[6]. A good example of this approach is called the TN (Newtonian Theory) approach (Earman, 1993, 31). The class of TN theses utilize Newtonian mechanics and gravitational theory, including the concept of absolute space. TN(o) states that the universe is at rest with relation to absolute space, while TN(v) states that the universe is in motion relative to absolute space, where v is the velocity of the universe. There can never be any empirical observations that will allow scientists to distinguish between these two theories. Therefore, TN(v) is empirically equivalent to TN(o). This example of course utilizes a physical theory that is out of date; however the advocates of this algorithm maintain that similar algorithms can be generated to produce empirically equivalent theories for other scientific theories.

André Kukla for example proposes "an algorithm for constructing indefinitely many empirical equivalents to any theory" (Kukla 1993, 1). He constructs this general algorithm from considering a specific case of empirical equivalence. Following

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[6] 'Algorithm' is used in a very general, nonmathematical, sense here.

Goodman, Kukla begins by defining something that is grue as something that is green when observed and blue if it is not observed. Thus based on this definition of grue, the theory that states all emeralds are green is empirically equivalent to the theory that states that all emeralds are grue. “Furthermore, the equivalence will survive any conceivable change in the range of observables and auxiliaries” (Kukla 1993, 4). This approach can be generalized in the following way, we can take any theory T with a specific observational consequence O and construct a theory T′ where T is true only when the universe is being observed, but while no observation is taking place the universe follows the laws of T′. Kukla then concludes that “one can find such a T′ for any T, and just as clearly, T′ is empirically equivalent to T” (1993, 5). Kukla admits that this construction might be a logico-semantic trick and that he does not claim that T′ theories are genuine competitor to T theories (Kukla, 1993, 5); however his main point is that its rejection has to be argued for. He believes that the algorithmic approach shows “that there *[are] empirically equivalent propositional structures to any theory.* The only question is whether these structures fail to satisfy some *additional* criteria for genuine theoreticity” (Kukla 1993, his italics, 5).

Stanford (2006) in *Exceeding our Grasp* provides the means to refute this type of empirical equivalence when he disagrees with the TN approach. He states that TN(v) and TN(o) do not make identical empirical predictions (2006, p. 13). The very thesis of TN(o) implies that no empirical evidence can be found for the claim of absolute rest, while the argument from underdetermination applies to claims that can possibly be empirically verified. As Stanford explains “the TN(v) variety pose no threat to the *approximate* truth of our theories: if the realist believes TN(o) when…TN(v) obtains, most of her theoretical beliefs about the relevant domain will be straightforwardly true” (p. 14). All that TN(v) shows is that we would be unjustified to hold any belief concerning the velocity of the universe in relation to space and therefore does not pose a real challenge to scientific realism. Stanford rightly points out that the algorithm used to produce the TN argument does not produce a case of local underdetermination, but a case of global scientific underdetermination. No amount of empirical evidence will ever be able to distinguish between TN(o) and TN(v) and therefore this example of the algorithmic approach fails. This argument can also be applied to Kukla’s algorithm. TN(o) and TN(v) imply that no empirical evidence can be found for the relative velocity of the universe to absolute space, while the argument from underdetermination applies to claims that can be empirically verified. All that the T′ variety of theories shows is that we can never be justified in asserting certain properties, such as relative velocity of the universe to absolute space or the color of emeralds when not observed, since no amount of evidence will enable scientists to distinguish between a theory that asserts this special property and one that does not. Thus Kukla’s algorithm produces a sceptical, global scientific underdetermination, argument of philosophical interest only and misses the mark of local underdetermination in science.

More generally, the algorithmic approach involves ad hoc adjustments to bring about underdetermination and the theories that it produces need not be taken seriously by philosophers or scientists. These ad hoc adjustments through the use of algorithms generated by philosophers cannot make short work of the task of producing genuinely distinct empirically equivalent theories. The procedure of producing genuinely distinct empirically equivalent theories is exactly what most theoretical scientists attempt to do over the course of their careers (Stanford, 15). It follows then that rather than producing empirically equivalent rivals to scientific theories using algorithms, philosophers ought to defer to the history of science for examples. Within the available philosophical literature, the pessimistic induction approach comes closest to utilizing an examination of the history of science in the above sense.

The Pessimistic Induction

The pessimistic induction states that, since the history of science shows that past successful theories, which were once thought to be true, have almost always turned out to be false, it follows that some of our current theories must be false as well and that we are not in a position to know when our theories *are* true. As Larry Laudan explains, "scientific theories of earlier eras exhibited an impressive sort of empirical support, arguably no different in kind from that enjoyed by many contemporary physical theories. Yet we now believe that many of those earlier theories profoundly mischaracterized the way the world was" (Laudan, 1984, 157). For example, before the Eddington eclipse experiment in 1919, Newtonian Physics had as much empirically evidence supporting it as the general theory of relativity. Both theories provided explanation for all the available evidence, until Eddington and his team during an eclipse observed that the light from a star behind our sun was bent around the sun in the manner predicted by Einstein's general theory of relativity, thereby proving that Einstein's theory was true and Newton's theory was false. Thus, even though Newton's theory was once held to be a successful theory, a new theory eventually emerged that was at one time empirically equivalent to Newtonian mechanics and in the end Newtonian mechanics was proven to be false. Several other examples can be found within the history of science, including the transition from the Ptolemaic earth centered universe theory to the Copernican theory and from Aristotelian Mechanics to Newtonian Mechanics (for more examples see Stanford 2006, 20). From these examples the pessimistic induction strategy for an argument from underdetermination states that since past successful theories have so often been shown to be false it follows that our current successful theories will also eventually and inevitably be shown to be false. Thus even our current and most successful scientific theories cannot be true and thus scientific realism is incorrect.

The pessimistic induction is not an argument from underdetermination, it is an inductive argument. For even though the falsification of one theory and the verification of another is often the result of two theories being underdetermined, underdetermination is not the main focus of the pessimistic induction, rather it is the falsification of the earlier successful theory that is the main element of this particular antirealist argument. An argument from local underdetermination ought to use two or more theories that are underdetermined based on the current available evidence to show that scientific realism is incorrect. The pessimistic induction does not focus on the issue of underdetermination, it instead uses historical cases of theory change in order to inductively conclude that our current theories are not true. Thus, the pessimistic induction is a strong antirealist challenge against scientific realism however it is an argument from induction, not an argument from underdetermination.

Unconceived Alternatives

Based on the pessimistic induction, Stanford rejuvenates another inductive argument from the history of science, called, following Duhem, the problem of unconceived alternatives (2006). Stanford maintains that through the history of science we have often occupied an epistemic position in which we have conceived of only one or a few theories that were empirically well confirmed, even though further inquiry would produce distinct alternatives that were empirically equivalent. Stanford states that "in the historical progression from Aristotelian to Cartesian to Newtonian to contemporary mechanical theories, the evidence available at the time each earlier theory was accepted offered equally strong support to each of the (then-unimagined) later alternatives" (2006, p. 19). For example, long before the general theory of relativity was even imagined by Einstein as a possible alternative, the empirical evidence that established Newtonian Mechanics as the most successful theory would also have supported the general theory of relativity. Stanford then lists over half a dozen more examples which he believes "suffices to illustrate that the pattern is characteristic of theoretical science across a wide variety of fields and historical circumstances" (Stanford, 20). Therefore, the history of science offers evidence for the claim that empirically equivalent alternatives with respect to available evidence for our best theories could be formulated, even if we have not been able to conceive of them at the time. If unconceived empirically equivalent alternatives to our best theories do exist then there is no way to justify belief in our current theories. As a consequence we cannot be confident that a theory is true, because that theory could have been developed, bases on inference to the best explanation, from a set of theories that did not include the theory that will eventually supersede it.[7]

A strength of the argument from unconceived alternatives is that unlike the theories generated by the algorithmic approach, all the theories under consideration in it are serious scientific possibilities. As with the pessimistic induction, the argument from unconceived alternatives calls into question the truth of our best and most successful theories. However, as Stanford notes, “the classical pessimistic induction notes simply that past successful theories have turned out to be false and suggests we have no reason to think that our present successful theories will not suffer the same fate” (2006, 19). The argument from unconceived alternatives states that throughout the history of every scientific discipline, we have “repeatedly occupied an epistemic position in which we could conceive of only one or a few theories that were well confirmed by the available evidence, while subsequent inquiry would routinely (if not invariably) reveal further, radically distinct alternatives” (2006, 19). These alternatives would be as well confirmed by the available evidence as our current most successful theories and thus they would be empirically equivalent relative to the empirical evidence available at the time. Thus,

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[7] For a further discussion of unconceived alternatives see chapter 3.

while the pessimistic induction questions the accuracy of our most successful theories based on the historical characteristics of science, unconceived alternatives questions the accuracy of our most successful theories based on the amount of competition that they have enjoyed since their conception. Stanford's argument from unconceived alternatives is a strong challenge against the scientific realist, for it shows how difficult it is for scientists to come up with all the possible alternatives to any theory, while that theory is under development.

The Case Study Approach

The third and final strategy in the literature for constructing an argument from underdetermination is the strategy that utilizes cases of underdetermination in science. Within the contemporary philosophical literature the majority of examples of underdetermination, even those utilizing this strategy, are examples of global scientific underdetermination. John Earman says that the lack of real world examples in these discussions "is a shortcoming of the philosophical literature and not a failure of the underdetermination [argument]" (1993, 31). In response to this shortcoming, Earman proposes to find some real world examples of local underdetermination. Earman starts off on the wrong foot, however, for his first example is the TN example which I argued is not an example of local underdetermination because no amount of evidence will ever enable us to distinguish between the TN theory that states that the universe is in motion relative to absolute space and the TN theory that states that the universe is at rest relative to absolute space. His second example concerns the topological features of space-time.

Given our restricted position in space, the observations that are available to us are restricted to events within our past light cone. Thus, our position in the universe is such that any observations made from Earth are restricted to those stars that we can see and thus these observations are not representative of the whole universe, assuming that our location in space is atypical. It follows that the observations we can make from our position in the universe do not allow us to determine the topological structure of the universe. Such topological features include, but are not restricted to, an open or closed universe and the compactness of space. As a result we cannot and will never be able to empirically distinguish hypotheses about the topological features of space-time. After giving these two examples, Earman states that “other examples could be given, but [he trusts] enough has been said to remove the worry that the underdetermination thesis….is vacuously true…” (Earman, 31).

Earman’s examples fail to establish that the argument from local underdetermination is a problem from scientific realism, for his examples establish global scientific underdetermination. The topological case also fails to show that local underdetermination is an issue in science. No amount of evidence will ever be able to distinguish between theories that posit different and distinct topological features of space-time, thus the problem of topological features is also a problem of global scientific underdetermination. This problem only shows the limitations of a scientific theory, much in the same way the TN example does. As with the velocity of the universe relative to absolute space in the TN example, the topological structures of space-time do not play a vital role within our most successful theories. Indeed, the general theory of relativity allows for many different topological features. For example, in order to make his theory fit a static universe, Einstein introduced a constant, called the cosmological constant that would counter gravity and keep the universe from contracting or expanding due to this dominant force. When Hubble observed that the universe was in fact expanding, Einstein called the cosmological constant the greatest blunder of his life. Yet Einstein’s theory was not abandoned; all that was needed to adjust the theory to fit the observation was to reduce the cosmological constant to zero; the general theory of relativity was by no means falsified (see Goldsmith, 1995 and Kirshner, 2004). Just as Einstein’s theory of general relativity allows for an expanding, contracting or static universe, it can also encompass an open or closed universe, all the possible geometries of space and any other topological structure that is underdetermined by the available evidence. Therefore, the example of the underdetermination of topological structures is of philosophical interest only and is not a problem that concerns the truth of our most successful scientific theories. In conclusion, Earman’s example displays the limits of our knowledge rather than real world examples of local underdetermination.

The argument against global sceptical arguments, such as the Cartesian demon, can be extended to Earman’s example of the topological structure of space-time. As Earman has noted, given our position in the universe our observations are restricted to events in our past light cone and thus we cannot distinguish between the various topological structures. Even if we were on the opposite side of the universe our position would be such that our observations would be so restricted, however within this restricted position we can still make observations that allow us to understand and determine the characteristics of the universe, including the laws that govern it. Thus as in the Cartesian demon sceptical scenario we are doing well epistemologically for we can gain knowledge within the system or in this case from our restricted position. The Cartesian demon argument attempts to question the amount of knowledge we can gain, while Earman's case study shows the limits of our knowledge. In both cases, we can rightly say we have knowledge and we can know which scientific theory is true, thus Earman's example fails to undermine scientific realism.

1.2 A New General Argument against Scientific Realism from Local Underdetermination

Some lessons can be derived from our discussion of the above of the approaches utilized to construct an argument from underdetermination. Firstly, an argument from underdetermination ought to come from cases of genuinely distinct but empirically equivalent theories and an understanding of how these cases are produced in science. Secondly, as was shown in the discussion of Earman's argument, the examples of underdetermination in science ought to be cases of local underdetermination, such that the competing theories are currently empirically equivalent with the possibility that further empirical data will be able to distinguish between them. For the very definition of local underdetermination involves cases of empirically equivalent theories which can be resolved given the right amount of evidence.

Now that the available arguments from underdetermination have been considered and some lessons have been drawn from their subsequent rejection, I move to construct a new general argument from underdetermination against scientific realism. To do this I will turn to two contemporary examples from science in which local underdetermination has actually arisen. These two examples of underdetermination will allow me to show exactly what problem for scientific realism stems from local underdetermination. These two contemporary examples are from cosmology.

Case Studies from Cosmology

The first example from cosmology concerns the phenomenon called gravitational lensing. Gravitational lensing is an effect produced when light passes a large body of mass and is pulled by gravity to the outer edges of that body causing the light to be focused on the outer edge rather than simply passing around it. Observing this phenomenon cosmologists calculate the mass of the stellar object in the middle of the lensing effect and conclude, based on the current theory of gravity, that the mass is not robust enough to cause the observed lensing of the light. Two theories have been developed to explain this phenomenon, dark matter theory and modified gravitational theory.[8]

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[8] It should be noted here that many astrophysicists believe that this issue has been resolved, however some still argue that there is room for doubt, see Moffat 2007 For the present purposes, i.e. developing a philosophical argument, this doubt is sufficient enough to allow the utilization of this example

The dark matter theory posits an unobservable matter that surrounds the observable matter in the universe. This dark matter adds to the mass of stellar objects such as galaxies and nebulae, but is undetectable by the human eye or any technology that we have so far developed, because it does not directly interact with the electromagnetic spectrum. Since according to this theory dark matter surrounds the observable matter in the universe it accounts for the missing mass needed to explain the observed gravitation lensing within the theory of relativity.[9] The second theory that has been posited to explain the observed phenomenon of gravitational lensing is a modification of the theory of relativity called the modified gravity theory. This new theory states that the force of gravity increases in proportion to the distance from the center of mass of a stellar body. Thus, under this theory, gravitational lensing is caused by the fact that the force of gravity is stronger on the outer rims of the galaxy or other stellar object causing the lensing effect. But the only empirical evidence available is gravitational lensing and thus is insufficient to justify a choice between the two competing theories. The two theories explain this phenomenon equally well and so they are in a state of underdetermination with respect to the available evidence.

The second example of underdetermination from Cosmology involves two theories that have been developed to explain the accelerated expansion of the universe. In 1998 astronomers attempting to determine the expansion rate of the universe unexpectedly discovered that the universe was not slowing down, as had been previously

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[9] The mass of the stellar object in the middle of the lensing effect is not robust enough to cause the observed lensing of the light.

predicted, but was in fact speeding up. Since this discovery several theories have been developed to explain this phenomenon; the two most prominent theories are the theory of dark energy and the theory of radial inhomogeneity.

The theory of dark energy posits an exotic form of energy that permeates all of space called dark energy. Dark energy is a repulsive anti-gravitational force that pushes against the galaxies and other large structures of the universe causing the expansion rate to increase in proportion to the distances between galaxies. Thus as the distances between them increase, the speed at which the galaxies move apart increases (see Kirshner 2002)[10].

The second theory that has been developed to deal with accelerated expansion is the theory of radial inhomogeneity which explains away the accelerated expansion by reducing it to an illusion created by our unique position in space. The theory of radial inhomogeneity entails that the cosmological principle, which states that the universe is homogenous, is incorrect. In a homogenous universe all matter, both visible and dark, is evenly distributed throughout the universe and so space is smooth. In a homogenous universe light can travel from its source through space unaffected by lumps in space caused by a larger or smaller amount of mass. In an inhomogeneous universe, matter is not evenly distributed and so light has to traverse the lumps in space caused by high mass density. Since we cannot directly observe these lumps in space, if we assume the universe

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[10] It should be noted here that dark energy is unrelated to dark matter; it is named dark energy simply because cosmologists are in the dark about the specific nature of this energy and that like dark matter it too does not interact with the electromagnetic spectrum.

is flat the undetected lumps in space make it look like the expansion rate of the universe is increasing. More specifically, the theory of radial inhomogeneity explains away the accelerated expansion of the universe by positing a lower than average mass density surrounding our own galaxy that creates the appearance of accelerated expansion (see Clarkson et al 2007).

Thus both the theory of dark energy and that of radial inhomogeneity explain the empirical evidence of the accelerated expansion of the universe. The theory of dark energy explains accelerated expansion by positing a repulsive energy that permeates all of space, while radial inhomogeneity explains accelerated expansion by positing an area of lower mass density that affects light such that it merely appears that the expansion rate is accelerating but it in fact is not. Currently the only evidence for both theories is the observation of the accelerated expansion of the universe; therefore the two theories are empirically equivalent relative to current observational data.

More examples of underdetermination in science could be given, but the above examples are sufficient to show that underdetermination is indeed a problem for scientific realism. A general anti-realist argument from underdetermination can be developed from the above cases. They have occurred due to the inability of our current successful theories to deal with anomalies detected by experiments conducted from within the paradigms established by these theories; in other words, these theories are empirically underdetermined since they are faced with anomalies that cannot be explained by accepted theories and adjusting these theories to cope with the anomalies produces adapted theories that are empirically equivalent relative to the observed anomalies. From the cases that I have examined I have shown that the underdetermination of theories by evidence arises from a theory's inability to account for observed anomalies. When a theory fails due to its inability to account for an unexpected observation, such as accelerated expansion or spooky action at a distance, empirically equivalent theories will and do arise. From the lessons learnt from these examples we can now generate a new general argument from underdetermination from antirealism

The New General Antirealist Argument from Local Underdetermination

Our general argument proceeds as follows: if experimenters are conducting an experiment under a theory T, being the most successful theory, and come up to an anomalous observation O, where anomalous here means that T cannot explain O, then T will often be modified into a set of theories T_1 to T_n in order to account for O inside the paradigm established by T. T_1 to T_n will contain any number of theories that utilize O as empirical evidence and thus these theories will be underdetermined. Given the resulting underdetermination of the theories by evidence, we cannot say which theories T_1 to T_n are true. Furthermore, the new general argument can be combined with the pessimistic induction, in so far as the pessimistic induction shows that underdetermination has arisen in the past. Therefore, based on this empirical equivalence, we cannot justifiably choose between any theory within the set T_1 to T_n. To help illustrate the general argument I will again turn to the above contemporary cases of underdetermination in science.

The first example concerning gravitational lensing, illustrates the general argument very well, for even though gravitational lensing was predicted by the general theory of relativity, the degree of gravitational lensing observed could not be accounted for by the theory. In other words, as discussed above, when cosmologists calculated the amount of mass that was creating the observed lensing effects. The amount of mass was insufficient to cause the lensing effect according to the theory of relativity. Thus, when observing the lensing effects caused by the gravitational attraction of certain bodies of mass in the universe, cosmologists observed an anomaly that the general theory of relativity could not explain. In order to account for this anomaly, two theories have been posited, the dark matter theory and the modified gravity theory which due to the equal support provided by the empirical evidence are underdetermined.

The second cosmology example also illustrates the new general argument very well. The observation of accelerated expansion of the universe was established independently by two teams of astronomers. The SCP and High-z Supernovae teams utilized measurements of supernovae to determine the expansion rate of the universe. The standard model in cosmology predicted that the rate of universal expansion would be decreasing due to the effect of gravity. However both studies showed that the rate of expansion was instead increasing. Thus the accelerated expansion rate was an unexpected or anomalous observation under the standard model of cosmology. The theory of dark energy is an adaptation of the standard model of cosmology. The introduction of dark energy into the standard model saved the standard model from falsification by the observation of universal expansion. On the other hand, the theory of radial inhomogeneity explains away accelerated expansion by suggesting that the standard model is incorrect and that the observations that suggest accelerated expansion are only an illusion created by our unique position in the universe. Currently the only empirical evidence available is evidence that suggests accelerated universal expansion. Thus the theories of dark energy and radial inhomogeneity are underdetermined, since they are equally supported by the anomalous data. These two theories illustrate the above general argument from underdetermination, for here again we have two empirically equivalent theories that have been developed to explain an unexpected or anomalous observation.

In conclusion, the above examples from contemporary science show that empirically equivalent or underdetermined theories arise when a base theory is faced with an unexpected or anomalous observation that is either independent from, i.e. not predicted by, the base theory or that contradicts it. Furthermore, based on the historical elements of the pessimistic induction, we see that underdetermination has arisen, presumably in the same manner, in the past as it has in the present. In the traditional view of underdetermination, as Earman states, “the anti-realist produces (or at least asserts the existence of) theories that are empirically equivalent in that they say the same thing about the observable” (1993, 19). Our general argument from underdetermination has been developed from contemporary examples of distinct theories that explain the same empirical evidence and are thus empirically equivalent. Thus, we see an additional proposition that ought to be added to the general argument. Each theory that is introduced to account for O, will provide distinct and incompatible accounts of the unobservable realm associated with O.

There are at least two reactions to the arguments from underdetermination, retreat from or defence of scientific realism. The rest of this thesis will take the latter approach and provide a defence of scientific realism. I intend to examine more closely the issue of underdetermination related to accelerated expansion by examining the theories of dark energy and radial inhomogeneity. The ways in which cosmologists have suggested dealing with the case of underdetermination concerning accelerated expansion will be examined and some philosophical insight into the problem of underdetermination will be drawn based on this discussion. To me, the case of underdetermination in cosmology concerning dark energy and radial inhomogeneity is the most promising in providing further insights into solving the problem of underdetermination and perhaps redeeming scientific realism from the argument from underdetermination. According to the contemporary philosophical literature, if underdetermination is empirically resolved in science, then we can be realists concerning the successful theory. This claim will be evaluated based on the further discussion of dark energy, radial inhomogeneity, and the new general argument from underdetermination. An argument against this defence will be considered, however it will be shown that ultimately the arguments from underdetermination, both global and local, fail to establish a good case against scientific realism.

Chapter 2: Defending Scientific Realism from the New General Argument

2.1 A Case Study; Accelerated Expansion of the Universe

In 1998, astronomers attempting to measure the expansion rate of the universe based on Type Ia Supernovae discovered that the universe is not slowing down in its expansion, as predicted by the Standard Model, but is in fact speeding up. The method used to establish accelerated expansion of the universe utilized Type Ia Supernovae (SN Ia). These explosions are 100,000 times brighter than the previously used candles, bright objects in the universe utilized as measuring points, called cepheid variable stars. With this high degree of luminosity, supernovae can be observed from well equipped ground based telescopes. However, the one downside to using supernovae is that unlike cepheid variable stars that have a long life, supernovae don't repeat their cycle, but if they can be found, supernovae are an invaluable tool for cosmology. The physics of supernovae can be analyzed based on the intensity and spectrum of radiation emitted from them, and most of those observed so far have the same luminosity. The most prominent type of supernovae are of the type Ia, called SN Ia. These supernovae are the result of a thermonuclear explosion of a white dwarf star, thus SN Ia are very similar to one another in spectral composition and intensity. Given this, the recession velocity of the SN Ia and therefore the rate of universal expansion can be determined by the redshift of the SN Ia.

Redshift is an expression of how the light waves produced by the SN Ia are directly affected by the recession velocity. The light waves produced by luminous objects in space are directly affected by the movement of that object. The wavelength of light increases if its source is moving away from the observer and decreases as it moves closer to the observer. The effect that movement has on the distance between waves is called the Doppler Effect.

The Doppler Effect is a phenomenon that affects all waves, a common experience of the Doppler Effect concerns sound. As a car approaches an observer standing on the side of the road, the volume and pitch of noise made by the car increases until it is at its peak right in front of the observer and while the car moves away from the observer the sound decreases until it cannot be heard anymore. Whereas the Doppler Effect produced by the car is displayed by the pitch of the sound of the engine, the Doppler Effect produced by luminous objects in space is displayed by the color of the light detected by the observer. If the wavelength is produced by a luminous object is large then the light that is produced will be red in color, while if the distance between the waves produced by it are small then the light that is produced will be blue in color. The wavelength of light is affected by the direction in which the luminous object is traveling in relation to the observer. Thus, if the light is closer to the red end of the spectrum then the luminous object is moving away from the observer and is said to be redshifted, if the light is closer to the blue end of the spectrum then the luminous object is moving towards the observer and is said to be blueshifted. Furthermore, the faster the object is moving away from the observer the fainter the object will be, while a brighter object indicates a slower velocity.

Dark Energy

The accelerated expansion of the universe follows from the observations of two separate research groups, the Supernova Cosmology Project (SCP) headed by Saul Perlmutter and the High-z Supernovae Search Team headed by Brian Schmidt, utilizing SN Ia as candles. The SCP observed redshifts of forty-two SN Ia (Perlmutter, 2001 and Perlmutter, 2003), while the High-z team studied sixteen SN Ia and both determined that the rate of universal expansion is increasing. Initially, both teams sought to establish whether or not the universal expansion rate was slowing down as the standard model predicted. However, as the teams began to study the SN Ia, they observed that the supernovae expressing a redshift near 0.5 were 25 percent fainter than expected. The expected luminosity was based on the standard model of the universe, which expresses a mass density of 1 ($\Omega m = 1$) with no cosmological constant. The luminosity of a supernova is directly related to the expressed redshift and the rate of universal expansion. As Kirshner explains, “if the universe is slowing down, then a distant supernova will appear brighter than if the universe is expanding at a constant rate” (2004, p.164). Thus, the fact that the supernovae expressing a redshift near 0.5 were fainter than expected implied that the light from the supernovae had to travel farther than was expected and thus the universal expansion rate is accelerating.

The prevailing theory to explain accelerated expansion is one that posits dark energy, a form of repulsionary force. The exact nature of dark energy is elusive; if it does exist dark energy could be an unknown ‘energy’ that is a property of space itself, an anti-gravitational force which pushes the galaxies apart, or it could be something else entirely. While the exact nature of dark energy is unknown, it is posited to be something similar to a non-zero cosmological constant (CC) that permeates all of space. The idea of a CC goes back to Einstein, who used it to adjust his equations in GTR so that the universe is static, for without the CC, the equations imply that the universe is dynamic, that it is expanding or contracting, a conclusion that Einstein could not accept (Kragh, 2007, 132). After Hubble showed through observation that the universe was in fact expanding, Einstein realized his mistake and saw no further use for the cosmological constant CC and, as the story goes, ended up calling the CC the greatest blunder of his life.

To bring the Dark Energy theory into contrast with the other suggested solution, an analysis of the suggested tests to determine whether or not the Copernican and Cosmological Principles are justified. The Copernican and Cosmological Principles are fundamental postulates that have been at the base of the cosmological models, including the prevailing Friedmann-Lemaître-Robertson-Walker (FLRW) model. The Copernican Principle states that our location within the universe is not privileged in any sense; the Milky Way is just another galaxy among billions within the Universe, it has no distinct position within the universe.

The Cosmological Principle, “states that our observations would roughly be the same, if we were located at any other place in the Universe” (Beisbart and Jung, 225). Thus according to the Cosmological Principle the universe is homogeneous and isotropic. For the universe to be homogeneous, it must look the same to separate observers performing their observations at any two different places within the universe. While, "within the definition of isotropy observers at the same point compare observations that are restricted to different directions" (Beisbart and Jung, 234) and given these observations the observer cannot distinguish between the directions observed. It may seem odd at this point for astronomers to hold that the universe looks the same for different observers in different places of the universe or that different directions may look the same for one observer.

The difference between homogeneity and isotropy concerns position. Isotropy concerns observations made from one position in the universe, thus it is a description of a particular location. As Beisbart and Jung state "within the definition of isotropy observers at the same point compare observations that are restricted to different directions" (234). If the universe is isotropic, then the observations made in different directions would be identical. To make this clearer we can consider spacetime as the subject being observed. As Beisbart and Jung state, "spacetime is *isotropic* if from any spacetime point no directions can be discriminated on the base of observations" (239). Conversely, homogeneity concerns any two different positions in the universe and is potentially a description of any positions in the universe. This means that no matter where two observers are in the universe their observations of the overall structure will be identical.

If you look out into the night sky you can easily see that the universe looks different depending on the direction in which you look in. In one direction you might see

Orion and in the other the Little and Big Dippers, and conclude that the universe does not look the same in each direction. However, physicists do not apply the terms homogeneous and isotropic to the small scale structures such as star constellations, galaxy clusters and the like, but rather to large scale structures such as the distribution of matter and energy, which, under these principles would be smoothly distributed throughout. As Ellis states "the standard models of cosmology are based on the assumption that once one has averaged over a large enough physical scale, *isotropy is observed by all fundamental observers…*[furthermore] when this isotropy is exact, *the universe is spatially homogeneous as well as isotropic*" (2006, Ellis' italics, 2).

According to the standard models of cosmology the structure of space-time is homogeneous and isotropic. If we took any two sections of space-time, any sections could be mapped into each other in the right way, then the universe is homogeneous and isotropic (Beisbart and Jung, 239). And so, we have two principles, the Copernican and the Cosmological, that are at the root of Cosmology. A group of astronomers, Clarkson et al, have proposed two experiments that would test these principles and in so doing resolve the issue of accelerated expansion without positing dark energy. This research group proposes that the observations that suggest that the expansion rate of the universe is accelerating is due to an illusion created by the structure of space-time itself. Thus, Clarkson and his associates propose to undermine the Copernican Principle by showing that we occupy a special place within the universe. This would effectively undermine the Cosmological Principle by showing that the universe is not homogenous and isotropic but is instead radially inhomogeneous. By radially inhomogeneous the authors mean that the mass density within the universe is not smooth, but is instead uneven. The unevenness is caused by areas of mass that are either more or less dense than the average mass density. Such a change in mass density would cause bumps in the otherwise smooth spacetime. In the case of radial inhomogeneity, the area of less or more mass would extend radially around our galaxy. Before moving on to discuss radial inhomogeneity and the proposed experiments to verify the existence of this structure, we must move to consider the relationship between homogenous models of the universe and dark energy.

As was said above the Cosmological Principle is at the root of the prevalent cosmological model called the FLRW model. This model is constituted from two important mathematical systems and two specific equations. In the FLRW model, the universe is also symmetrical and can be described by a set of geometries called the Robertson-Walker geometries. The Friedman and Lemaitre equations which describe the dynamic structure and evolution of the universe combined with these geometries produce the FLRW model. It was according to this model that the SPC and high-z teams observing the SN Ia expected to find that universal expansion was slowing down. However, as discussed above the observations instead showed that the expansion rate is speeding up rather than slowing down and in order to preserve the FLRW model a nonzero cosmological constant is required. Thus the dark energy theory is a direct product of this model and so it follows that another explanation for the accelerated expansion can be produced by negating the hypothesis that the universe is homogeneous and isotropic.

In “A General Test of the Copernican Principle”, Chris Clarkson et al. propose that the traditional approach to testing the Copernican Principle, that of developing models that do not involve this Principle and then subjecting them to empirical tests, is not an efficient test. Furthermore, the majority of astronomers do not agree with this approach and argue against it by appealing to Occam’s razor. The simpler models are the homogenous and isotropic models, such as the FLRW Model. The traditional approach to testing for inhomogeneity is model dependent, i.e. the scientists develop a model and then try to make that model fit observation. Clarkson et al believe that rather than developing an inhomogeneous model and trying to make it fit observation, unbiased observations should be made first and then the FLRW model should be scrutinized based on those observations (Clarkson et al, 1).

If the universe is radially inhomogeneous, then the observed redshifts that have led to the hypothesis of accelerated expansion can be accounted for by the nature of space itself rather than the speed at which the SN Ia are moving. Radial inhomogeneity implies that there are areas of space which contain more mass than other areas within the universe, thus the gravitational force exerted by these areas is higher than other areas within the universe. The higher amount of gravity causes space to curve which in turn affects the light waves given off by SN Ia to appear as though they have been altered due to an increase in the velocity of the source. These curved areas increase the distance between the light waves in much the same way as an accelerated recession velocity would, thereby causing the observed effect that has lead Cosmologists to conclude accelerated expansion (Clarkson et al, 2).

Before we consider how Clarkson and his team have proposed to confirm their theory while falsifying the theory of dark energy, we will move to a consideration of how cosmologists are adding further constraints to the theory of dark energy and why this does not count as confirmation of that theory. For example one team of cosmologists are trying to determine, more accurately, the expansion rate of the universe. This research is effective in determining the rate of expansion more accurately than the supernovae research groups were able to, however it is not effective in distinguishing between the theories of radial inhomogeneity and dark energy.

2.2 How not to solve underdetermination issues in science

A recent study utilizing the XMM-Newton (x-ray multi mirror Newton) space based observatory has been conducted in order to put further limitations on the equation of state that describes dark energy. The XMM-Newton is a space based telescope capable of detecting, absorbing and imaging x-rays, thereby enabling scientists to detect objects at great distances. This project is believed to have provided data that, as Rapetti et al claim, has provided “a direct and independent method by which to measure the acceleration of the universe, providing additional discriminating power for dark energy studies” (2005, pg. 556). However, even if it is shown that further refinement of the parameters governing accelerated expansion provides more discriminating power for dark energy studies, this will still not enable scientists to discriminate dark energy theory from the theory of radial inhomogeneity. Providing more evidence for accelerated expansion, adding to the empirical evidence that required the development of the two theories that are now underdetermined, will not enable scientists to discriminate between the various models of the theories of dark energy, however the theory of dark energy and the theory of radial inhomogeneity will still be underdetermined.

Since the observation of accelerated expansion in 1998 by both the High-z team and the SCP, more empirical evidence has been found from independent studies, studies of other candles, i.e. not SN Ia, that support the hypothesis of accelerated expansion. As was stated above, one such study is 'The XMM-NEWTON Ω project' performed by D.H. Lumb et al, which utilizes the new satellite, XMM-Newton, to observe a sample of high redshift galaxy clusters (GCs). The satellite based observatory, XMM Newton, can detect the distant GCs by detecting the X-rays emitted by them, and so this observatory was used to determine the rate of expansion based on GCs. The goal of this study was "to measure the luminosity and the temperature of the clusters to a precision of [approximately] 10%, leading to constraints on the possible evolution of the luminosity-temperature (L_x-T_x) relation, and ultimately on the values of the matter density, Ω_M, and to a lesser extent, the cosmological constant Ω_Λ" (2004, pg. 853).

The method involved in the XMM Newton project utilizing the GCs is much the same as that employed in the experiments utilizing the Supernovae. If the recession velocity of a GC is great enough, the GC itself can act as a candle in much the same way as Supernovae. As the GC moves further and further away from the observer, the wavelength of the x-rays waves emitted by the GC itself will become greater and this distance can be used to determine the recession velocity. Thus, as with the supernovae study, the XMM Newton project sought to determine the expansion rate by observing the redshift of these candles.

The further confirmation of accelerated expansion is however, by no means further confirmation of the existence of dark energy. As was shown above, both the theory of dark energy and the theory of radial inhomogeneity are both based on the observations of accelerated expansion. Thus, any further confirmation of accelerated expansion is not further confirmation of dark energy or of radial inhomogeneity, but is simply further confirmation of the observation that has lead to the underdetermination of the two theories. Now an objection could be made against the sceptical approach to these studies. For the study by Rapetti et al claims that the XMM Newton observations put a constraint on dark energy and thus it is indeed a study that confirms its existence.

At first this objection seems well warranted, however the deciding factor will be what exactly the scientists mean setting further constraints on dark energy and how exactly they go about doing this. Cosmologists are setting further constraints on dark energy by refining the measurements of mass density and accelerated expansion. They then use these measurements to choose between the various models of dark energy. The Rapetti et al study utilizes the GC surveys, along with the SN Ia surveys and a survey of the cosmic microwave background, CMB (2005). This analysis examines two dark energy models, the model that utilizes the cosmological constant as discussed above and the scalar field model. The scalar field model avoids the fine tuning of initial conditions that is necessary for the cosmological constant and also allows for an evolving function of redshift, meaning as the universe expands the redshift of galaxies throughout the universe increases in proportion to the expansion rate (Rapetti et al, 556). Rapetti et al apply the three surveys to set limits on the two models for dark energy; this is most evident when they conclude that “the SN Ia and cluster data provide the primary source of information on the evolution of dark energy. Of these, the SN Ia data currently contribute the strongest constraints” (2005, 562). This data can only be used once a tighter constraint on the mass density is established by utilizing the CMB and GC studies. The mass density, as was noted above in our discussion of the SN Ia surveys in the nineties, puts limits on the expansion rate of the universe, even if we posit an anti-gravitational force like dark energy. Thus this study is attempting to further understand the nature of accelerated expansion which would effectively set limits on dark energy if it does indeed exist. Of course a more developed understanding of the nature of accelerated expansion could also lead to a further understanding of the cosmic voids that have been posited to explain away accelerated expansion. If we can determine the exact value of redshift then we can determine the size of the void surrounding our place in the universe that makes the light appear to be redshifted.

In conclusion, the further confirmation of accelerated expansion will not allow scientists to confirm the theory of dark energy while falsifying the theory of radial inhomogeneity. Even granted that the combined observational evidence allows scientists to discriminate between the various models of the theory of dark energy, it does not allow us to discriminate between the theories of dark energy and radial inhomogeneity. Thus, we are still unable to discriminate between these two theories, because they are still underdetermined by the currently available evidence.

What this means is that, utilizing the language of the general argument from underdetermination, further confirmation of the observation that led to the development of the two underdetermined theories will not allow scientists to discriminate between the various theories within the set of underdetermined theories. Clarkson et al, however, have proposed an experiment that will be enable scientists to discriminate between the two theories of dark energy and radial inhomogeneity. An examination of this experiment will enable me to determine how underdetermination issues are resolved in science and what epistemic value such methods might have in salvaging scientific realism from the new general argument from underdetermination.

2.3 How to Solve Underdetermination Issues in Science

Radial Inhomogeneity

In order to test for radial inhomogeneity and thus test the Cosmological Principle and the FLRW model, Clarkson and his associates have proposed an experiment which will test the consistency relation between the distance derived from the observed Hubble rate of an SN Ia and the distance derived from the luminosity of that SN Ia. In other words, the astronomers propose to find an SN Ia and test the distance measurements based on Hubble rate (H) by comparing it with another distance measurement, the luminosity distance (D). These two distance measurements are distinct distant measurements, because the Hubble rate (H) is based on the recession velocity of the SN Ia and is thus a direct result of the redshift, while luminosity distance (D) is based on the physical understanding of the candle and the observed brightness or luminosity of the object. If radial inhomogeneity is correct and a curve in space does exist, then the wavelengths of the SN Ia will be stretched such that it will look as though the light has been affected by a high acceleration rate. Thus, if the theory of radial inhomogeneity is correct, H will be affected by curves in space in that the wavelength of the SN Ia will be increased, the light will be reddened, while D, the luminosity of the SN Ia, will be less affected.

If the two distance measurements are equal (fig. 1), then the Cosmological Principle is further confirmed and accelerated expansion due to dark energy is the best explanation for the observed phenomenon. The observed redshift of the supernova would be best explained by accelerated expansion. If the relation is not consistent (fig. 2), then the Cosmological Principle and the FLRW model are not correct and the universe is radially inhomogeneous. In figure one the lengths of both the solid arrow and the dotted line are the same representing the fact that the two distances are equal. However, in figure two, the lines are not the same length, the one represented by the dotted arrow (H) is affected by the curved area of space which is represented by the square in the diagram making the supernovae appear to be where the dotted circle is when in actuality it is where the solid circle is as determined by the luminosity distance (D). Not only is the distance affected by the area of inhomogeneity, but so is the redshift. If radial inhomogeneity is correct the curve in space will increase the wavelength of the light from the supernovae making it appear as though the supernova is receding away from the Earth at an increasing rate. Thus figure one represents an isotropic and homogenous universe where the propagation of light is affected by the accelerated expansion, while figure two represents a radial inhomogeneous universe where the propagation of light is affected by the curvature of space caused by an area of less mass.

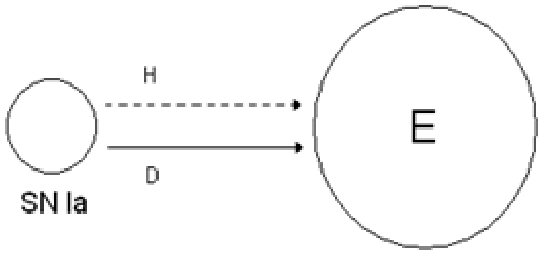

Figure 1

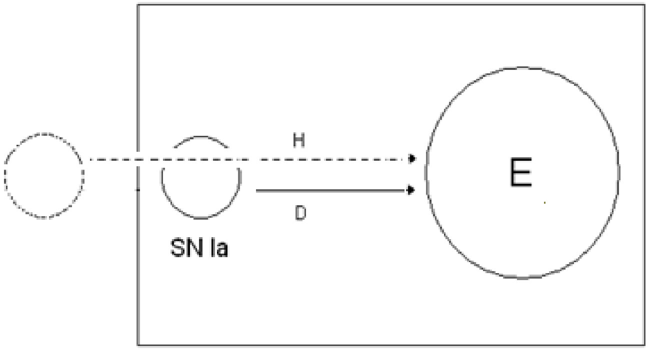

Figure 2

How to solve underdetermination issues in science

At present the dark energy theory and radial inhomogeneity theory are empirically indistinguishable, the evidence gathered to date equally supports that the universe is accelerating or the hypothesis that the FLRW model is incorrect and the universe is in fact curved in some sections and thus inhomogeneous. However, the experiment proposed by Clarkson et al has the ability to falsify or verify the FLRW model, which will enable them to distinguish between the two underdetermined theories. Clarkson et al propose an independent test that has the ability to falsify one of the theories, while verifying the other. If it is shown that the distance measurements of H and D is equal, then the universe is indeed homogenous and isotropic, and the theory of dark energy will be verified and the radial inhomogeneity theory will be falsified. However, if it is shown measurements of H and D are not equal and the universe is not homogenous and isotropic, then the radial inhomogeneity theory will be verified and the dark energy theory will be falsified.

The test that Clarkson et al have proposed is a fundamental test of both dark energy and radial inhomogeneity, because it is a test of the assumptions underlying both theories. As we saw above, the theory of dark energy resulting from the observations of accelerated expansion presupposes a homogenous and isotropic universe. Thus, the Clarkson et al test will attempt to falsify dark energy by falsifying one of its fundamental auxiliary hypotheses and will in return verify the radial inhomogeneity theory by confirming that the universe is indeed inhomogeneous. Going back to our general argument, a means of resolving an issue of underdetermination is to test, empirically or experimentally, an auxiliary hypothesis of one of the theories within the set of underdetermined theories. Therefore, underdetermination issues in science can be resolved by testing the auxiliary hypotheses of the various theories within the set T1 to Tn.

In conclusion underdetermination issues do indeed arise in science, these issues are, however, resolved empirically. Since theory choice between two or more empirically equivalent theories is done by empirical means either by testing the assumptions of a theory or discovering independent empirical observations, we can be realists about the resulting theories; we can know when a theory is true. However, the antirealist can argue that this type of defense against the general argument from underdetermination disregard the temporal nature of the issue.

2.4 The Temporal Objection

Such an antirealist objection would proceed as follows: the amount of time between the development of the set of underdetermined theories to the empirical confirmation of one theory over another is relative to each situation. For example, the first observations that established accelerated expansion came from two separate teams of astronomers over ten years ago (Kirshner, 2002) and yet the theories that explain this observed phenomenon are still underdetermined. This is a problem because the theories of dark energy and radial inhomogeneity are mutually exclusive theories. Dark energy is based on a model of the universe that is homogenous and isotropic, while the theory of radial inhomogeneity is based on a model of the universe that is inhomogeneous. Thus, given the current situation of underdetermination, not only can we not know that the theory of dark energy is true or that the theory of radial inhomogeneity is true, but we cannot know whether or not the models that these theories are built upon are true.

Going back to the general argument then we see that when a set of theories T_1 to T_n is underdetermined, the realist position is unjustified not only concerning the theories within the set, but also concerning the base theories or models. Furthermore, from the epistemic position created by having underdetermined theories, we are unable to determine when the issue will be resolved, or indeed even if it will be resolved at all. Scientific realism states that we can know when a theory is true or at least approximately true, however when two theories are underdetermined we are not able to determine which theory is true. Thus, even though it is possible for scientists to gather more evidence in favour of one theory, it takes time to do so and until the issue is resolved we are unable to say which theory is true. Furthermore, it is not just the truth of the underdetermination theories that is at issue, but also the truth of the base theories. The theories of dark energy and radial inhomogeneity are underdetermined and thus we cannot know which theory is true. Furthermore, as we have seen these theories are built upon models of the universe, the theory of dark matter is built upon the FLRW model and so until the issue of underdetermination is resolved we are not in a position to judge the truth of either model. It is of little consequence for the realist to claim that after the issue of underdetermination has been resolved we can then be realists about the theory and its base theory or model. In conclusion, the new general argument from underdetermination establishes that local underdetermination is indeed a problem for scientific realism. For given a set of underdetermined theories, we cannot be realists about any theory within the set or the base theory that those theories attempt to modify and salvage. In conclusion, contrary to the conclusions drawn from my consideration of the accelerated expansion problem, the fact that underdetermination issues in science are resolved over time does not save scientific realism from the argument from underdetermination. For during a situation of underdetermination it is impossible to tell when the issue will be resolved. Until a resolution comes about we are unable to be scientific realists about the underdetermined theories and the base theories involved.

The above case study of the underdetermined theories dealing with accelerated expansion shows how scientists attempt to resolve underdetermination issues in science.

However, as was shown above these examples do not salvage scientific realism from the general argument from underdetermination. There is no means of determining when an issue of underdetermination will be resolved and until it is resolved we are not in a position to be realists concerning any of the theories that are underdetermined or the base theories they are built upon.

2.5 Murder Realism and the New General Argument

One objection that could be made to the problem that the new general argument raises for scientific realism is that it does not challenge the fundamental tenet of scientific realism. This objection can be best formed if we consider the analogy of murder realism.[11] Let us suppose that we want to be murder realists. A murder realist believes that whenever a dead body has been found a murderer can be found, provided the individual has not died of natural causes or by accident, and proven guilty based on empirical evidence. Furthermore, even if there are initially multiple suspects and then the evidence points towards only one suspect, say there are only one set of bloody boot prints leaving the crime scene, the murder realist maintains that a suspect or a group of suspect will be found and proven guilty. As the investigation is being conducted, the detectives involved are in a similar epistemic position to the scientists who are trying to determine one theory over another. The fact that the case is not solved immediately, but takes several days to solve does not undermine the murder realist’s claim that it can indeed be

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[11] Here I am drawing on the remarks of Mark Wilson from the 2010 Waterloo graduate conference.

solved.

Analogously, the scientific realist claims that our most successful scientific theories are successful because they are true, or at least approximately true. Thus the scientific realist can claim that a case of local underdetermination can be resolved; that one of the theories within an empirically equivalent set can be determined to be true. As in the murder realist case, the scientific realist accepts that the issue cannot always be solved within a relatively short period of time. It may be cold comfort to the scientists involved that the issue will eventually be resolved and that had things been different the issue may have been resolved faster, but the scientific realist is quite comfortable with the fact that the issue of underdetermination, of the local sort, can and will be resolved.

Indeed, many scientific realists maintain that underdetermination is resolved in many different ways. As with the case of murder realism, the fact that the determination of the truth of one theory from a set of empirically equivalent theories takes an indeterminate amount of time does not undermine or challenge the scientific realist claim that scientific theories are approximately true. Therefore, the suspension of belief in a base theory and the theories that are empirically equivalent, relative to the data at some particular time, does not undermine the realist claim that over all scientific theories are at least approximately true.

In conclusion, chapter one and two have shown that the arguments from global underdetermination produce and illustrate nothing but some possibly philosophically interesting limits on our knowledge, while the argument from local underdetermination does indeed raise a problem for scientific realism. In answer to the global underdetermination arguments such as the demon controlled world and other thought experiments that question the ontological reality of the world we live in, the scientific realist can reply that our theories are true or approximately true within the world we live in. If we limit our standard of truth to the world in which we reside, whether or not it is the real world, we can justifiably maintain that our theories are approximately true. The global underdetermination cases that can be developed out of the algorithmic approach underline the limits of our knowledge. For example, the cases derived from Newtonian Mechanics shows that we can never be justified in asserting that we have found all of the true properties of the universe, since no amount of evidence will allow us to distinguish between a universe that is at rest or in motion relative to absolute space. The topological structure of spacetime problem, discussed by Earman, also shows the limits of our knowledge while not calling into question scientific realism, all that it shows is that we cannot distinguish between the possible topological structures of space, due to our finite role and position in the universe. Both the algorithmic approach and the real world example of the topological structures of space time are philosophical problems rather than genuine problems for scientific realism.

While considering the argument from local underdetermination, we have established that locally underdetermined theories arise within science when an unexpected observation is made that a current theory cannot explain. The murder realist-scientific realist analogy then showed that the new argument from underdetermination is in fact unsuccessful in its attempt to undermine scientific realism, for the scientific realist can still maintain that one theory will be shown to be true or at least approximately true given enough time. Thus the general argument from underdetermination has been shown to be a methodological problem that can be resolved through appeals to science. The above case from contemporary cosmology showed that local underdetermination issues are resolved in science by searching for independent observations that establish one theory over the other theories that are empirically equivalent relative to currently available evidence. Therefore, the above considerations of anti-realist arguments from underdetermination have shown that both types of arguments from underdetermination, global and local, are unsuccessful in their attempts to dispute scientific realism. The only anti-realist arguments that survive are the pessimistic induction and Kyle Stanford’s argument from unconceived alternatives. The rest of this thesis will be a discussion and analysis of Stanford’s unconceived alternatives and the pessimistic induction.

Chapter 3: The Problem of Unconceived Alternatives

3.1 Chasing Stanford

In Exceeding Our Grasp, Kyle Stanford reintroduces and reworks the argument from unconceived alternatives. This argument stems from Duhem's worries about eliminative inferences in science, in which scientists use empirical tests to choose one theory from two or more underdetermined theories by eliminating the competing theories. Duhem's worry, and thus Stanford's worry, is that "such an eliminative inferential procedure will only guide us to the truth about nature if the truth is among these competitors in the first place" (Stanford, 2006, 28). Stanford's claim then is that eliminative inferences only allow us to choose among the conceived theories that are up for debate, while the history of science shows that we are often unable to conceive of the theory that will eventually become empirically well confirmed. Prior to Einstein, for example, Newtonian Mechanics was shown, through eliminative inferences, to be the best theory. However, had the general theory of relativity been conceived of at the time, it would have been the best, most empirically confirmed theory. As Stanford says, "the historical record suggests that in science we are typically unable to exhaust the space of likely, plausible, or reasonable candidate theoretical explanations for a given set of phenomena before proceeding to eliminate all but a single contender, but this is just what would be required for eliminative inferences to be reliable" (2006, 29).

Stanford does not intend to undermine the importance of eliminative inferences altogether; he only wishes to point out the limited usefulness of such inferences. When eliminative inferences are used to exclude alternatives, they can be incorrect, for they disregard the possibility of unconceived alternatives; when such inferences are used simply to choose between various possibilities that exhaust the list of all possibilities, they can be useful, for they can show that one possibility is more likely than the other available possibilities. For example, if we are trying to choose between two explanations, eliminative inferences based on the available evidence will allow us to determine which possibility is more likely. Stanford uses the following example:

> "These tracks were made by a dog or a wolf.
>
> No one has ever seen a wolf [in California].
>
> Therefore, these tracks were made by a dog" (2006, 29)

The fact that no one has seen a wolf in southern California does not make it impossible that the tracks do indeed belong to a wolf; it only makes this possibility more unlikely than the possibility that the tracks belong to a dog. The implausibility that the tracks were made by a wolf allows us to eliminate this option, leaving us with the more likely explanation that the tracks belong to a dog. Furthermore, the two options, whether the tracks were made by a dog or a wolf, is an exhaustive set, for the tracks are too small to have been made by a bear and too large to have been made by a coyote, thus ruling out the claim that the tracks were made by a wolf leads necessarily to the claim that they were made by a dog. The application of eliminative inferences in this context is justified and reliable, for it is clear that the chances of hitherto unconceived alternatives existing in the above example are remote. Once eliminative inferences are applied in science, Stanford maintains, we can be anything but confident that the possibility of unconceived alternatives is remote. Indeed, Stanford believes “that the historical record of scientific inquiry itself provides abundant evidence that the specific requirements for the reliable application of eliminative inference…are routinely *unsatisfied* in the context of theoretical science conducted by creatures who are cognitively constituted as we are” (his emphasis, 2006, 32). Thus, eliminative inferences are useful if and only if they are used when deciding between an exhaustive set of hypotheses.

Stanford’s argument from unconceived alternatives is a different inductive argument than the pessimistic induction, which deals with past and present theories, because the argument from unconceived alternatives concerns the theorists of past and present science. The pessimistic induction claims that past scientific theories have been shown to be false despite the virtues they have in common with our current most successful theories and that since we are in the same epistemic position, our current most successful theories must also be false. In contrast, as Stanford states, the argument from unconceived alternatives points out “that present theorists are no better able to exhaust the space of serious, well-confirmed possible theoretical explanations of the phenomena than past theorists have turned out to be” (2006, 44). Thus the problem of unconceived alternatives is not an argument from underdetermination as classically conceived. Indeed, Stanford construes “the problem of unconceived alternatives not as competing with the traditional challenges of underdetermination and the pessimistic induction so much as bringing out what was most significant and compelling about those challenges to begin with" (2006, 45).

According to Stanford, his argument from unconceived alternatives reworks the two main challenges for scientific realism outlined by the pessimistic induction and the argument from underdetermination. The first problem, adapted from the argument of underdetermination, is what Stanford calls the new induction. The new induction claims that science continually occupies a predicament of underdetermination, wherein scientists have repeatedly failed to conceive of scientifically serious alternatives to accepted theories that would be as well confirmed by the available evidence. Some of these alternative theories have eventually been conceived and then accepted by future scientists and, Stanford maintains, this same predicament, by induction, can be applied to our current scientific theories. For example before it was conceived the theory of relativity was an unconceived alternative to Newtonian mechanics since it is supported by the same empirical evidence that once supported Newtonian mechanics. Furthermore, the theory of relativity eventually replaced Newtonian mechanics and it follows by induction, according to Stanford, that the theory of relativity will eventually be replaced by what is at this moment an unconceived alternative to it.

The second problem that Stanford's argument further develops is the problem of unconceived alternatives, which points out that historical patterns outlined within both the pessimistic induction and the new induction are due to our inability to develop an exhaustive list of alternatives from which to draw the most successful theories based on eliminative inferences. If science is indeed continuously faced with the issue of underdetermination between the most successful theories and some unconceived alternatives, as the new induction maintains, then scientific realism is false, because we can never know when our most successful theories are true, or even approximately true. Furthermore, if the means we use to choose the most successful theory out of a set of empirical equivalent theories is unreliable, due to the fact that the set of theories involved are not chosen from an exhaustive list of possible scientific theories, then our current most successful theories are probably not the best theories to explain the available evidence. So far the arguments in favour of the new induction and the problem of unconceived alternatives have not been well supported; the above historical case utilizing the change from Newtonian mechanics to the general theory of relativity was, if anything, cursory. As Stanford rightly claims, "this discussion makes clear…how much ultimately depends on my claim that the historical record supports the new induction and the problem of unconceived alternatives in the way that [has been suggested]" (2006, 47). Thus, I will now turn to Stanford's discussion of three historical cases that provide some direct evidence for his claim. Once Stanford's three historical cases have been discussed, I will move to consider an argument proposed by Hardin and Rosenberg (1982) that attempts to show that unconceived alternatives do not challenge scientific realism because the referential terms of past theories are carried over into contemporary theories. I will then discuss Stanford's argument against this position and then introduce a newly revised philosophical position called structural realism. It will be shown that structural realism is the most promising approach to dealing with Stanford’s new induction.

The examples Stanford uses are not from Physics, where one might expect examples of the new induction and unconceived alternatives would be easily found, but are instead from biology. This is a somewhat surprising move because as Stanford points out, “the revolutionary and counterintuitive character of such conceptual innovations as the electromagnetic field, general relativity, and virtually all things quantum mechanical has left many of those knowledgeable in the physical sciences with a healthy respect for presently unconceived possibilities” (2006, 51), while biological science affords “a staunch tradition of scientific realism among biologists and philosophers of biology alike…” (2006, 52). Thus it may seem unlikely that Stanford will find any cases of unconceived alternatives within biology. The examples that Stanford discusses are from the specific area of biology that deals with generation and inheritance. Stanford is indeed able to find many examples that add support to the argument from unconceived alternatives and provides a detailed analysis of each example. For the purposes of this thesis, I intend only to examine three of the historical cases cited by Stanford as evidence for his argument from unconceived alternatives.

3.2 Case Studies from Biology

The three historical cases concern theorizing about generation and inheritance; contemporary biology distinguishes between these two separate phenomena maintaining that they occupy distinct scientific landscapes however such a distinction is a relatively new development. As Stanford explains, “until comparatively recently…the phenomenon of inheritance, reproduction, development, growth, and repair were typically regarded as aspects of a single process, forming a single domain of theorizing and a single field of study" (2006, 52). This field of study was simply described as the study of generation and is generally described as unproblematic, for philosophers and historians of biology maintain that later theories were anticipated in some general way by earlier theories. The first example, and thus Stanford's first case study, concerns the nineteenth century teleomechanical theory of generation.

The teleomechanical theory denied that a purely mechanical explanation could accurately describe embryological development. Thus, philosophers and historians of biology often maintain that contemporary molecular genetics must be, in some sense, counted among the broad class of theories that were rejected due to the teleomechanical assumption that a purely mechanical explanation could not accurately describe embryological development (Stanford, 2006, 53). However, some historians and philosophers of biology consider the denial of a mechanistic explanation as evidence that nineteenth century biologists conceived of this type of explanation as a possible alternative. Indeed, as Stanford maintains, "when nineteenth century teleomechanists denied that *any* purely mechanical process could produce the goal-driven phenomena of embryological development…there is surely some sense in which contemporary molecular genetics (and its purely mechanical account of ontogeny) must be counted among the broad class of theories thereby pre-emptively rejected" (2006, emphasis his, 53). Thus, even though the eventual alternative was conceived of only in very broad and general terms, the fact that they were not fully considered effectively undermines the power of the eliminative inferences that the scientists used.

Another example that Stanford discusses is from the eighteenth century. During the eighteenth century there was a fundamental theoretical conflict between the preformationists and the so-called epigeneticists. The preformationists believed that embryos were fully developed in one way or another at the very moment of conception, while epigeneticists believed that embryonic parts were produced in stages during development. However, as Stanford points out, "it is an historical commonplace that without any sophisticated chemistry or grasp of molecular complexity and without the benefit of cell theory, *neither* group could form any concrete conception of *how* complex structures could form sequentially in the developing embryo by purely material processes" (emphasis his, 2006, 54). Thus, without a sophisticated cell theory or a chemistry, both groups failed to accurately conceive of an alternative mechanistic theory for embryonic development. Without these sophisticated auxiliary hypotheses, these two groups explained complex organic processes by attributing life to matter itself. When Spallanzani conducted an experiment that showed that spontaneous generation was impossible, he, according to Stanford, believed that the theory of "preformationism [was] supported or even simply established by the experimental demonstration that such spontaneous generation does not occur" (2006, 54). The refutation of spontaneous generation was taken to be an experiment that justified the elimination of any mechanistic explanation of generation. According to Stanford, this eliminative inference from the above mentioned experiment was unjustified and flawed, because no fully developed mechanistic explanation was on the table at the time such an experiment was conducted. Furthermore, a mechanistic explanation of generation was eventually developed, thereby refuting the claims of the eighteenth century biologists and illustrating that these groups of scientists failed to conceive of and consider a likely and indeed successful alternative.

It was not until the end of the nineteenth century that an interest in developing a materialistic or mechanistic explanation for generation and heredity arose. As Stanford explains this “dramatic momentum [came] from such converging influences as increasingly detailed microscopic observations, the development of cell theory, and advances in experimental hybridization” (2006, 60). Each of these developments was prompted by Charles Darwin’s *Origin of Species* and the questions that it brought about concerning the mechanisms of evolution. Darwin himself developed a theory of pangenesis in his book *Variations of Animals and Plants Under Domestication,* this theory posited physiological units that Darwin termed “gemmules”. Darwin’s theory of gemmules was published four years after a similar theory by Herbert Spencer, however Darwin’s theory was much more developed than Spencer’s, which was vague and more of a primer than a theory. Thus, as Stanford indicates, “Darwin’s much more concrete and more clearly mechanistic hypothesis of pangenesis would exercise a greater influence on subsequent theorizing about generation and inheritance, and it was Darwin’s theory that later theorists of generation would feel obliged to confront and discuss, even if only to abuse” (2006, 61). During the time of the development of Darwin’s pangenesis theory, another alternative remained unnoticed and unappreciated.

This alternative concerned "Mendel's discovery of the ratios with which parental traits reappear in subsequent generations of hybrid offspring and their suggestive implications concerning the mechanism of heredity" (Stanford, 2006, 61). The paper describing this discovery was published in the journal of the Brno Natural History Society, however it lay largely unknown on the shelves of libraries all across Europe. Mendel's discovery was the foundation for the theory of genetics that emerged in the late nineteenth century, however it lay largely unnoticed by the biologists of the early nineteenth century. Carl Nägeli replied to Mendel's experimental results simply by suggesting to Mendel that he repeat it using Hawkweed, a particular plant utilized by Nägeli that ironically does not exhibit the Mendelian segregation of traits (Stanford, 2006, 61). It was not until Hugo de Vries, Erich von Tschermak and Carl Correns made some microscopic observations concerning chromosomal behaviour which confirmed Mendel's theory of segregation that Mendel's ideas got the deserved recognition. Thus, as Stanford concludes, "this case constitutes a particularly interesting source of support for the problem of unconceived alternatives, as it offers an especially clear testament to the inability to even recognize a particular unconceived alternative theoretical explanation for which the data, to modern eyes, seem to cry out" (2006, 61-62). The support this case offers is made even more evident due to the fact that Darwin was not influenced by Mendel's discoveries at all. Darwin spent several decades theorizing and gathering evidence for his theory of pangenesis, generation and heredity since he started to develop it in 1868. According to Stanford, Darwin believed that the parents of an offspring were the first cause of that offspring; he did not consider that the parents and the offspring shared a common cause. Darwin maintained that the shared characteristics between the offspring and parents were due to some shared tissue that was contributed materially to the offspring. However, as Stanford recognizes, the common cause was eventually shown to be “the hereditary material found in a shared germ line ultimately producing them both” (Stanford, 2006, 68).

In conclusion, the case studies which Stanford utilizes in Exceeding Our Grasp, illustrate the shortcomings of eliminative inferences within science. Stanford shows that biologists often utilize eliminative inferences to choose from a set of theories that is not exhaustive. The example from the eighteenth century showed that both the preformationists and the epigeneticists failed to conceive of a materialistic alternative explanation of generation and embryonic development. Due to their inability to develop such an alternative, the eliminative inference that the eighteenth century biologists conducted was from a non-exhaustive set of theories. These scientists failed to conceive of and develop a theory that would be later accepted as true.

Stanford claims that the case study of nineteenth century biology also shows the limitations of eliminative inferences. Mendel’s theory of recessive and dominant genes went largely unnoticed by Darwin and his contemporaries and was not considered as a possible alternative. This effectively limited the set of theories being considered during the eliminative inference between Darwin’s pangenesis theory and Spencer’s theory. This example makes Stanford's case even stronger, for Mendel's theory was precisely the theory that came to be accepted once other scientists independently found the required evidence. Therefore, as Stanford states, the historical record shows that "we have repeatedly failed to conceive of equally well confirmed alternatives to our best theories that were sufficiently scientifically serious as to be actually accepted by later scientists and scientific communities" (2006, 188). Given that our ancestors have failed to conceive of equally well confirmed alternatives to their best theories, there is reason to believe that our current theories will suffer the same fate.

Furthermore, if we consider the above contemporary examples from Cosmology we now have reason to doubt that the theories that are currently underdetermined by the evidence, even those not considered by the current work, are an exhaustive set of possible alternatives. Consider the example from cosmology concerning the accelerated expansion of the universe. As was mentioned above, the apparent accelerated expansion of the universe was an unexpected observation which changed the way we view the universe and our place within it. The previous cosmological model depicted the universe as expanding or contracting at a slow and universal rate. The observations made in 1998 drastically challenged and effectively changed this view and now Cosmologists are faced with many possible alternatives, the most prevalent being Dark Energy and Radial Inhomogeneity. Thus, before 1998 these two theories were unconceived alternatives, they were well supported by the evidence available to cosmologists before the 1998 supernovae observations. The idea of a cosmological constant was first proposed and utilized by Einstein in order to make his equations describe a nonexpanding universe. This idea was later dropped due to the observations, made by Hubble, suggesting an expanding universe. However, the fact still remains that, like Mendel's hypothesis, a universe expressing a cosmological constant was first conceived of and then later dropped only to be then reinstated many years later. Thus, our view of the universe has gone through some drastic changes in the last ten or so years and these changes could have been fully anticipated by the scientists of the past, but remained as unconceived alternatives. Furthermore, it stands to reason, based on Stanford's argument, that the theory that will eventually win out, whether it will be radial inhomogeneity or dark energy, will then itself at some point come up against an observation that it cannot account for. The theory will inevitability be replaced by a new theory that shares a similar observational background as its predecessor and thus can be considered an unconceived alternative.

3.3 Arguments against Stanford

The majority of available defences of scientific realism in the philosophical literature are directed towards the pessimistic induction rather than Stanford's new induction. However, since both of these inductions are based on the historical record, most objections to the pessimistic induction are applicable to the new induction. Stanford considers many of these objections within his book and he concludes "that both the problem of unconceived alternatives and the pessimistic induction itself survive even the best recent efforts to defend realism from the specter of the historical record" (2006, 142). For the purposes of this work, I will consider only the most promising objections to the new induction, covered by Stanford, and Stanford's responses to them.

Appeals to Maturity

The first objection, that Stanford considers, maintains that the historical examples used in his case studies are examples of scientific theories that did not make a novel and accurate predictions and thus were not mature scientific theories. Thus according to this objection these historical examples lacked the successes that our contemporary successful scientific theories have and thus these examples can be rejected. For example, the preformationists and the epigeneticists theories of the eighteenth century by Stanford's own admission never made any novel predictions. Without enough sophisticated chemistry and an understanding of cellular generation, neither the preformationists nor the epigeneticists could form an accurate understanding of the material processes involved in embryonic development (Stanford, 54). Thus the realist maintains that neither theory enjoyed any real predictive or explanatory success and were eventually replaced by a more sophisticated theory. As biology progressed, the theories that came after the preformationists and the epigeneticists theories were exceedingly more successful. However, even these theories were eventually rejected, due to their inability at predicting further evidence. For example, as we saw above, Darwin's theory maintained that the only source of change in an organism was the environment; it did not predict the existence of dominate and recessive genes and therefore was not a successful theory (see Stanford, 2006, 60-75). With the rejection of these examples, the Scientific Realist claims that the evidential basis from which any induction can be made becomes extremely restricted (Stanford, 2006, 144).

Stanford's reply to appeals to maturity

Stanford maintains that "*bare* appeals to maturity and/or strict standards of success threaten to undermine the explanationist defense of realism itself" (Stanford, his italics, 2006, 144). By the explanationist defense Stanford means the very argument that scientific realism hinges upon the no miracle argument. The no miracle argument, and thus scientific realism, maintains that the success of our theories is best explained by the truth or at least approximate truth of those theories. The scientific theories of the past, including the theories that are used to support the pessimistic induction and the new induction, were held to be true or at least approximately true by the scientists of the appropriate era. Thus, according to Stanford, it now seems as though scientific realism ought to include further conditions that will explain the explanatory power of our successful theories. Therefore, Stanford concludes, "if we now insist that further conditions must be satisfied in order to trigger this explanatory demand, we will need a principled rationale for why just that sort of success remains a reliable indicator of the truth of the theories that enjoy it, when others that equally excited our initial admiration and credence failed to do so" (2006, 144).

Furthermore, Stanford argues that appeals to maturity also run the risk of being circular and tautological. If the criterion of a mature theory is one that involves that theory adhering to certain properties that our current successful theories have, then appeals to maturity presuppose scientific realism in order to support scientific realism. The only account of maturity that Stanford considers is from Boyd who suggests that mature science begins at “what one might call a ‘take-off point’, a point in the development of the relevant scientific discipline at which the scientific theories are sufficiently approximately true and comprehensive” (Boyd, 1980, 627). Before such a point is reached, the scientific theories will not possess the degree of reliability that is characteristic of science and thus can be characterized as pre-scientific. Thus, Boyd’s definition of a mature science is far too dependent on the scientific realist claim that our current successful theories are approximately true and so Stanford concludes that any appeal to maturity needs to be based on an objective standard; a standard that does not presuppose scientific realism.

Even if such an objective standard can be defined, Stanford maintains that attempts to undermine the significance of some of the historical examples only works to limit the historical challenge that the inductions offer. Even the most severe critics of the inductions acknowledge that some of the historical theories were mature or at least successful enough that the supporters of them were justified to support it. He considers the nineteenth-century wave theory of light which regarded light to consist of a wave motion propagated in a medium called the ether, a rarefied elastic material substance. The wave theory of light generated many empirical successes, including being able to explain and predict the phenomena of reflection, refraction and polarization. Furthermore, the wave theory also managed to deal with a reductio ad absurdum derived by Poisson to show that the wave theory was incorrect. As Stanford explains this reductio predicted "that there should be a bright spot of light at the center of the shadow of a perfectly circular disk" (2006, 146) a prediction which was rather counter intuitive, but was later confirmed by experiment. These successes suggested that the nineteenth century wave theory of light was indeed true however it was later shown to be false. Therefore, Stanford concludes that "past theories that at one time enjoyed the kinds of empirical support that have traditionally led their defenders to suppose that they must be true…have nonetheless ultimately turned out to be false" (2006, 146). Thus, Stanford claims that even though scientific realists are justified in their rejection of some of the historical examples used by his new induction, there are enough historical examples of the kind needed by these inductions for them to be successful.

Hardin and Rosenberg's Response

One realist strategy against the new induction is to maintain that it underestimates the degree to which the central terms of the now unsuccessful theories refer to objects in the world and the extent to which these theories should be judged by present lights. Thus, Hardin and Rosenberg argue that past theories need not have been descriptively accurate in order for their central terms to refer to real objects in the world. For example, Hardin and Rosenberg claim that even though the nineteenth-century wave theory of light described light as a wave that is permeated through the ether, the terms 'light wave' and 'ether' still referred to something real in the world. The realist is justified to hold as Hardin and Rosenberg maintain "that 'ether' referred to the electromagnetic field all along" (1982, 613-14). Thus, since the central terms of our past theories were indeed referential, it follows that the central terms of our current most successful theories will also turn out to be referential, thus we can be scientific realists about the objects those central terms refer to.

Stanford maintains that this strategy only manages to salvage scientific realism in part, because it shows that the central terms refer, but does not show that the descriptions are accurate. More precisely he maintains that "the sort of account envisioned by Hardin and Rosenberg secures a history of successful reference for terms in discarded theories only by explicitly divorcing their reference from the question of the accuracy of those theories and thus abandoning the specifically theoretical beliefs of the very sort for which the realist hopes to convince us to share her realism in the case of current theories" (2006, 148). Thus, since the central terms of the theories of the past were accurate only in so far as they referred to objects in the world and the theories did not provide accurate descriptions, we cannot be realists about the descriptions of the unobservables that our current successful theories provide. Therefore, according to Stanford, even if Hardin and Rosenberg show that the terms in our successful theories are referential, they fail to show that our theories theoretical descriptions are also accurate (Stanford, 2006, 149).

3.4 Structural Realism and the Optimistic Induction

In "Structural Realism: The Best of Both Worlds?" John Worrall says that Hardin and Rosenberg's claim that Fresnel was talking about the electromagnetic field all along is far too chartable: Worrall states that "for a historian to reserve the option of holding that a scientist did not fully understand his own theory; but to allow that he may have totally misunderstood it and indeed that it could not really be understood until some fifty years after his death…is surely taking 'rational reconstruction' too far" (1989, 117). In the nineteenth century, Fresnel described light as an elastic vibration through a solid called the ether, he was not mistaking the electromagnetic field for the ether, but was describing a substance which he believed existed. That being said, Worrall does believe that an element was carried over in the shift from Fresnel's theory of light to Maxwell's theory of light, but that "it was rather less than a carrying over of the full theoretical content or full theoretical mechanisms (even in 'approximate' form')" (1989, 117). What was carried over in the shift, according to Worrall, was the structure or form of Fresnel's theory of light. Even though Fresnel misunderstood the nature of light the change from his theory to Maxwell's shows that he understood the form or structure of light. This view leads Worrall to support and reconceptualise structural scientific realism. I will move to consider structural scientific realism before moving to consider how Fresnel's structural claims were carried over to the electromagnetic theory of light and what this means for the problem of unconceived alternatives.

Structural Realism

While scientific realism is defined as the philosophical view that maintains that we know that our most successful scientific theories are approximately true, structural realism maintains that "it is reasonable to believe that our successful theories are (approximately) structurally correct" (Worrall, 2007, 125). Thus, structural realism gives a definition of approximate truth in that it states that the structural claims of a scientific theory are true. By the structural claims of a scientific theory the structural realist means the interactions or relations between entities as predicted or described within a scientific theory. Steven French and James Ladyman define structure as “model independent relations between phenomena…these relations are not supervenient on the properties of unobservable objects and the external relations between them” (2003, 46).

The Optimistic Induction

In support of structural realism, philosophers such as Worrall and McArthur construct an optimistic induction in answer to Stanford’s new induction. One such optimistic induction concerns the change from Fresnel’s theory of light to Maxwell’s theory of light. These two theories are, according to the antirealist, incommensurable, meaning the descriptions of nature provided by both theories are distinct and as we have seen Stanford utilizes this case to support his new induction. Worrall, however, says that the structure of light was carried over from the nineteenth century theory of light to Maxwell’s theory of light. By this he means that the equations describing the relationship between light and the objects in the universe were carried forward. As Stanford points out in his discussion of Hardin and Rosenberg, the nineteenth century theory of light was predictively accurate in that it predicted and later confirmed that light shone onto an opaque disc creates a light spot in the middle of the shadow of that disc. Since this prediction was later confirmed by experiment, the theory that would later replace Fresnel’s theory, Maxwell’s theory, would have to be able to explain this phenomenon just as well. In order to do this, Maxwell’s theory had to incorporate the equations of Fresnel’s theory. Furthermore, according to Worrall, Fresnel’s theory accurately described the structure of light in two other relations, reflection and refraction off a metal disc on a ninety degree angle, he explains that:

> “Letting I^2, R^2, C^2 be the intensities of the components polarised in the plane of reflection of the incident, reflected and refracted beams respectively and I'^2, R'^2, X'^2, the intensities of the components polarised at right angles to the plan of reflection of the incident, reflected and refracted beams respectively, then Fresnel’s equations state that these variables will always be related by
>
> $R/I = \tan(i-r)/\tan(i+r)$ $R'/I' = \sin(i-r)/\sin(i+r)$
>
> $X/I = (2\sin r.\cos i)/(\sin(i+r)\cos(i-r)$ $X'/I' = 2\sin r.\cos i/\sin(i+r)$
>
> Where i remember is the angle at which the light is incident on the glass (and therefore also reflected from it) while r is the angle at which the light is refracted into the glass” (2007, 134).

According to Worrall, other than a reinterpretation of the variables involved, these equations are retained entirely within Maxwell’s theory of light. The difference between the two theories is one of how they understand the nature of light. In Fresnel’s theory, the variables I, R, X, I’, R’ and X’ measure the maximum distance that a wave displaces a particle of the ether, while in Maxwell’s mature theory those variables measure the variations in the strength of the electromagnetic field. From our point of view then, Worrall continues, Fresnel was wrong about the nature of light, a wave displacing an elastic medium and yet he was correct in terms of structure for he was correct “that optical effects depend on *something or other* that oscillates at right angles to the direction of transmission of the light” (2007, 134). Thus, even though Fresnel had the nature of light incorrect, he was correct, according to our relative position in the history of science, in his observations and the equations he used to describe those observations. He observed that light reflects off an object at a right angle to the point in which it is transmitted and developed equations to describe this relation. Maxwell in developing his theory of light, retained Fresnel's correct equations, but abandoned Fresnel's description of the nature of light as a wave traveling through an elastic medium, replacing this description with one involving variations in the electromagnetic field. Furthermore, as Dan McArthur explains, "this is also the case with the shift from Maxwell's theory to modern quantum mechanical theories of light, where Fresnel's equations still hold as limiting cases" (2008, 16).

Another example of structure being carried over from one theory to another, as Dan MacArthur maintains, "is the case of Kepler's equations describing planetary motion that survive in Newton's much more comprehensive theory of universal gravitation. These equations express the 'interaction properties' whereby we can predict planetary motion" (2008, 15). Even though these two theories make very different ontological claims, claims about the nature of the universe, the structural claims of the theories, the way they describe and predict planetary motion, are the same. In fact, the ontological claims are so different that Stanford would count the change from Kepler's theory to Newton's theory as evidence for his unconceived alternatives thesis. Therefore, the interaction properties of both these theories represent stable structure that persists across theory change. This stable structure also persists across the change from Newtonian mechanics to Einsteinian mechanics.

Furthermore as Worrall explains, Newtonian mechanics is a limiting case of Einstein's theory of relativity. He claims that "Newton's theory, for example, although 'rejected' (i.e. no longer regarded as the best available theory) continues to be applied to slow moving bodies…" (1982, 206). Whenever the velocity of an object is significantly lower than the speed of light, the predictions of the theory of relatively are empirically indistinguishable from Newtonian mechanics. Thus, even though Newtonian mechanics has been superseded by Einsteinian mechanics, some structural claims of Newtonian mechanics, i.e. the equations describing the movement of objects at relatively low velocities, are still accurate for some cases.

The Optimistic Induction

What all this means for Stanford's argument from unconceived alternatives is that even though Maxwell's theory of light might eventually be replaced by a new emerging theory as the history of science shows, the history of science also shows that the structure of the theory might be retained. The latter point is what Worrall and other structural realists call the optimistic induction. As was shown, further support for this argument comes from several other case studies from physics, including the retention of structure from Kepler's theory of planetary movement to Newton's and later Einstein's theory. Secondly, it has been pointed out that Newtonian mechanics is a limiting case of Einstein's theory of relativity. As was explained, if an object is moving at a relatively low velocity, Newtonian mechanics still holds and the predictions made are identical to those made by the theory of relativity. Thus, the optimistic induction shows that structure is sometimes carried forward from one theory to another and by induction, since structural claims have been carried over from previous theories to superseding theories the structural claims that our current theories will be carried over into future theories that are currently unconceived. Before we move to consider Stanford's objections to structural realism, we must move to consider Worrall's definition of maturity which will provide an objective account of mature theories. This definition of maturity enables the structural realist to deny some of the case studies that the pessimistic induction and the argument from unconceived alternatives utilize.

According to Worrall the best definition of a mature theory in science is one that is independent and objective. Worrall defines a mature theory as one that has enjoyed or does enjoy genuine predicative success (1989, 113). Based on this definition it is clear why Worrall, McArthur and other structural realists have focused on the specific cases while constructing the optimistic induction. For example, since Fresnel's theory of light was predictively successful, in that it predicted that a light spot would appear in the middle of the shadow produced when light was shown through an opaque disc, it must be shown that its structural claims have been carried over into the superseding theory. Thus, a structuralist account of the change from Fresnel's theory of light to Maxwell's was needed. Since Newton's theory was predictively successful a structuralist account of the change from Newtonian mechanics to the theory of relativity was also needed.

3.5 Objections to Structural Realism

Galton’s Stirp Theory: a counter example

However, even with this definition of maturity, the structural realist still faces some of Stanford’s case studies from biology. One such case study that Stanford discusses during his criticism of Worrall’s formulation of structural realism is Galton’s stirp theory of genetics[12]. Galton’s theory, according to Stanford, was a predictively successful ‘mathematical formalization’ of inheritance and yet it has been abandoned in contemporary genetics. Thus, Stanford argues, if structure is mathematical formalizations then Galton’s mathematical formalization of the law of inheritance would count as a structural claim. In order for this objection to be applicable to the definition of structure given by structural realists since 2006, we can add that Galton’s mathematical formalization also describes the structural relations between the unobservable entities that came to be called genes. In other words, the structure he described should be carried over into contemporary genetics. According to the law of inheritance, which Galton called the ancestral law, two parents contribute one-half of the total heritage of the offspring, grandparents contribute one-eighth and so on. Now Stanford admits that “the formal mathematical relationship described by the Ancestral law can certainly be unearthed by significantly persistent digging” into contemporary genetics (2006, 182), however, he also claims that it is equally true that contemporary genetics does not utilize Galton’s Ancestral Law. Contemporary genetics does not describe any fundamental aspects of the

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[12] The word stirp comes from the Latin for roots

mathematical structure of inheritance. Thus Galton's stirp theory, according to Stanford, is a counter example to structural realism, for it makes a structural claim that is not carried forward into the superseding theory.

Objections to Stanford's counter example

Based on Stanford's discussion of the stirp theory, it is not entirely clear that Galton's theory was successful or even widely accepted within the scientific community, thus it is questionable whether or not this particular case study counts as a counter example to the structural realist optimistic induction. By Stanford's own admission, Galton believed his theory was incomplete. Indeed, Stanford points out that in his discussion of the stirp theory "Galton allows that in the case of heredity we are quite ignorant about many aspects of the corresponding 'elections,' including the stirpal analogues of the 'numbers of electors,' their 'qualifications,' their 'motives,' the 'number of seats,'… and any number of further details…" (2006, 92). Furthermore, Stanford says nothing about how the other biologists of the time viewed Galton's theory. This is an important omission because the argument from unconceived alternatives must use scientific theories that were once held to be true, but were eventually replaced by other theories which could have been just as easily developed from the evidence that supported the later accepted theory. Stanford also does not include a discussion of the predictive success of Galton's theory he only mentions that Galton's theory was predictively successful when he addresses structural realism. Therefore, since Galton himself questioned the accuracy of the stirp theory and it did not have any mentionable support from other biologists, this particular theory is not support for unconceived alternatives, nor does it count as a counter example to the optimistic induction. Of course, the rejection of Galton's stirp theory from the set of case studies that support the argument from unconceived alternatives is what Stanford would call a Pyrrhic victory for the realist, for many other case studies stand in support of the argument from unconceived alternatives, it is simply a matter of finding them.

Even if we were to suppose that Galton's theory was indeed predictive and successful, Stanford's claim that the ancestral law not is utilized within contemporary genetics does not rule out the possibility that the law is a limiting case of contemporary genetics. Indeed, his discussion gives evidence that Galton's mathematical formulization has been carried forward into contemporary genetics as a limiting case. Stanford accepts that the law of ancestral heredity still remains as a mathematical formalization of a very simplistic level of heredity and can still predict the distribution of genetically defined characteristics in particular breeding populations (2006, 182). Stanford's objection is that this law does not describe any fundamental or significant aspect of heredity. This relationship between Galton's stirp theory and contemporary genetics ought to seem familiar. In his discussion of the change from Newtonian Mechanics to Einstein's theory of special relativity, Worrall explains that Newton's equations of motion are still correct when applied to relatively low velocities, velocities that are far lower than the speed of light, but when applied to higher velocities Newton's equations fail. Worrall concludes that Newton's equations can be considered as a limiting case of the theory of special relativity. Therefore, if we can accept that Newton’s equation of motion is a limiting case of the theory of special relativity, we can also accept, based on Stanford’s discussion, that Galton’s law of inheritance is a limiting case of contemporary genetics.

Answering the charge of atypicality

In “Miracles and Models” Worrall admits that the theory shift from Fresnel to Maxwell is unrepresentative of the whole of the history of science. To this charge he answers that “in all other cases, the best that can be argued is that, once a science has reached maturity, the mathematics of any theory replaced in a ‘scientific revolution’, while not retained fully intact, is instead ‘quasi-retained’ *modulo* the ‘correspondence principle’” (emphasis his, 2007, 142). As we have seen a means of quasi-retaining the structural elements of a theory is by utilizing the theory as a limiting case. Since Newtonian mechanics can be used to predict the motion of an object at a relatively low velocity in a manner that is equivalent to the special theory of relativity, Newtonian mechanics is a limiting case of the special theory of relativity. Furthermore, since the law of ancestry of Galton’s stirp theory accurately describes the distribution of genetic characteristics for certain populations, it can be considered as a limiting case of contemporary genetics.

In conclusion, Stanford’s counter example to structural realism’s optimistic induction fails for he is incorrect when he states that Galton’s law of ancestry was not carried over into contemporary genetics. Galton’s law can be understood as a limiting case of contemporary genetics. It can still be used to accurately describe the distribution of genes within certain populations. Secondly, Worrall accepts the charge that the case study from optics is atypical, but he affirms that even when the structural claims of a theory are not retained within the superseding theory, they are still quasi-retained. Indeed, the above argument against Stanford's counterexample supports Worrall's claim of quasi-retention, for when structural claims are not fully retained within the superseding theory, they are often retained as limiting cases. For example, the structural claims of Galton's stirp theory is still applicable to certain populations and Newtonian mechanics is still applicable to objects traveling at low velocities.

What Structures are Correct?

Another criticism that Stanford makes against structural realism is that the structural claims of a theory are elusive and often very difficult to separate from ontological claims. As he states, "it is not at all clear that we can plausibly distinguish the claims of a theory about the *structure* of natural phenomenon from its 'content', 'ontology' or claims about the nature of the entities it describes" (2006, 181). Furthermore, Stanford argues that structural realism needs to provide a means of identifying the structural claims that will be carried over. Without this criterion the structural realist defence fails, for without it the realist cannot know what claims are correct. Thus, according to this argument, the assertion that the structural claims of a theory are correct is just as ambiguous as the traditional realist position that scientific theories are approximately true.

What we can know to be true

Structural Realism shows that the structural claims of certain mature theories, for example Fresnel’s optics, and Kepler’s laws of motion, have been carried over into their superseding theories, and that by induction, we can be confident that these same structural claims will be preserved when or if our current theories are eventually replaced by more accurate theories. Thus one way of telling which structures will be carried over is through the historical analysis of science. Of course even with this in hand, we will be unable to determine which newly devised structural claims of our current theories are correct and will be carried over, however the lack of such knowledge does not pose a significant problem for the optimistic induction of structural realism.

By asking what new structural claims will be carried over from our current theory to the next, Stanford is simply pointing out an inherent weakness with inductions. An induction only allows for a generalization, it does not allow for specific conclusions. Just as Stanford asks the structural realist to be more specific about what structural claims will be carried over, the structural realist can ask Stanford which theories will eventually be replaced by a currently unconceived alternative. The only difference between these two inductive arguments is that Stanford’s argument is far more overarching than Worrall’s. Stanford claims that all the major theorists within contemporary science have failed to conceive of the alternatives that eventually replace the dominant theories, while Worrall’s induction claims that some structural claims within contemporary theories will be carried over into the next superseding theories. The weakness of Stanford’s induction is that an optimist can still maintain that some, or at the very least one of our contemporary theories will not be falsified eventually, while the weakness inherent in Worrall’s induction is that the pessimist can still maintain that no structural claims within our contemporary scientific theories will be carried over. However, even with these criticisms both inductions still stand.

Structural realism is the most promising realist strategy for dealing with the problem of unconceived alternatives. It is the only realist strategy that provides an optimistic induction that counters the pessimistic induction inherent in Stanford’s argument from underdetermination. What is required in order to fully utilize this realist strategy is further research into the history of science in order to find more case studies that support the optimistic induction.

Ch. 4 Conclusions

In chapter one a distinction was made between arguments from global sceptical underdetermination, global scientific underdetermination and local underdetermination. Arguments from global sceptical underdetermination are designed to call into question all knowledge, even knowledge of the self and the world around us. However, it was shown that these arguments do not effectively call into question scientific knowledge, for even if we humans are being deceived by some evil demon, we can still gain knowledge of the world that the demon has created and apply it to the system. Secondly, if the imagination of the demon is limited, the knowledge we gain from inside the system could be applied to the outer world, the world of the demon. Thus global sceptical arguments are of philosophical interest only they do not call into question scientific knowledge. As we saw arguments from what I call global scientific underdetermination are aimed at the short comings of specific types of knowledge and are thus not fully sceptical. As we saw in chapter one, John Earman's underdetermination argument based on our inability to determine the topological structures of space-time is an argument from global scientific underdetermination, because no amount of evidence that we can gather would be able to distinguish between the various theories of topological structures allowed by the theory of relativity. However, even with this inherent limitation in the theory of relativity, we can and have still gained knowledge from the theory itself. Thus, just as we can gain knowledge from within the system created by an evil demon, given the inherent limitations within a scientific theory, we can still gain knowledge from within that boundary. In other words, even if we cannot gain knowledge about the topological features of space-time, we can still gain knowledge about the universe, such as the degree to which the light from a distant star gets bent by the sun's gravity. Lastly, we saw that local underdetermination involves two or more theories that are in principle eventually distinguishable, for example Newtonian mechanics and Einstein's theory of relativity were at one time underdetermined, however the eclipse experiment of 1919 allowed physicists to verify the theory of relativity and falsify Newtonian Mechanics.

In the last section of chapter one a new general argument from local underdetermination was constructed that showed that local underdetermination is a possible problem for scientific realism. This argument states that when a scientific theory comes up against an anomalous observation that it cannot explain, new theories are developed to explain this unexpected phenomenon. These new theories are underdetermined, because the only available evidence is the anomalous observation and the evidence of the old theory. Now given enough time these will be distinguished however until that time we cannot be realists about either theory and therefore traditional scientific realism fails.

In chapter two we examined how scientists distinguish between two or more underdetermined theories and found that they do so by attempting to find independent evidence for one of the underdetermined theories or by testing the auxiliary hypotheses of one of the theories. We then entertained the possibility that the temporal objection would work against our defense of scientific realism. The temporal objection states that even though issues of local underdetermination are resolved empirically, this resolution takes time and that until the issue is resolved, we cannot be realists about either theory. However, through a consideration of an analogy between scientific realism and murder realism, a new version of scientific realism was developed that maintained that we can eventually determine when our scientific theories are true. Since, local underdetermination is resolved empirically, the new general argument calls into question traditional scientific realism but not the above formulation of scientific realism.

Chapter three began with a discussion of the second major problem for scientific realism, Stanford's argument from unconceived alternatives. In Exceeding our Grasp Stanford establishes that the history of science shows that past scientists have been unable to conceive of all the possible scientific theories to explain a given phenomenon and, as a result, their theories, once head to be true, were later shown to be false. He then argues that, by induction, we are currently in the same situation; our current theories will eventually be shown to be false and replaced by the same scientific theories that could be developed based on the empirical evidence we currently have and therefore scientific realism is false. It was then shown that Stanford's argument from unconceived alternatives does indeed challenge traditional scientific realism, but does not undermine the philosophical position of structural realism.

Therefore, it has been shown that traditional scientific realism, the view that we know that our current scientific theories are true or at least approximately true, is a naively optimistic view of science. The new general argument from underdetermination shows that in a case of underdetermination, we are not in a position to confirm or deny either theory and so we cannot be traditional realists about any of the theories. This part of the new general argument was called the temporal objection. In response to the temporal objection, a different scientific realism was identified which maintains that science will eventually discover the truth. It was also shown that traditional scientific realism is unable to respond to Stanford's argument from unconceived alternatives. However, the optimistic induction of Worrall's structural scientific realism shows that some structural claims are carried over from theory to theory, or that at the very least, structural claims of past theories are used as limiting cases of the superseding theory. As a result structural realism maintains that we know that some structural claims of a currently successful theory are true.

Structural realism is the most promising realist strategy for dealing with the problem of unconceived alternatives. It is the only realist strategy that provides an optimistic induction that counters the pessimistic induction inherent in Stanford's argument from unconceived alternatives. What is required in order to fully utilize this realist strategy is further research into the history of science in order to find more case studies that support its optimistic induction. Thus, structural realism still has a long way to go until it can be maintained that it fully undermines Stanford's argument from unconceived alternatives. There is a lot of work being done to accomplish this and structural realism may be strong enough to fully eliminate such pessimistic inductions as the argument from unconceived alternatives.

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