Re-enchanting Realism in Debate with Kyle Stanford

Emma Ruttkamp-Bloem

Department of Philosophy, University of Pretoria, Private bag X20, Hatfield, Pretoria 0028, South Africa
e-mail: Emma.Ruttkamp-Bloem@up.ac.za

Abstract

In this article, against the background of a notion of 'assembled' truth, the evolutionary progressiveness of a theory is suggested as novel and promising explanation for the success of science. A new version of realism in science, referred to as 'naturalised realism' is outlined. Naturalised realism is 'fallibilist' in the unique sense that it captures and mimics the self-corrective core of scientific knowledge and its progress. It is argued that naturalised realism disarms Kyle Stanford's anti-realist 'new induction' threats by showing that 'explanationism' and his 'epistemic instrumentalism' are just two positions among many on a constantly evolving continuum of options between instrumentalism and full-blown realism. In particular it is demonstrated that not only can naturalised realism redefine the terms of realist debate in such a way that no talk of miracles need enter the debate, but it also promises interesting defenses against inductive- and under-determination-based anti-realist arguments.

Keywords: Realism, evolutionary progressiveness, continuity, reference, truth, unconceived alternatives

1 Introduction

In this article a new version of realism in science is outlined that does more justice to our current understanding of the functioning of science and its history than either traditional scientific realism or instrumentalism can do. The proposed version of realism, referred to as 'naturalised realism', is 'fallibilist' in the unique sense that it captures and mimics the self-corrective core of scientific knowledge and its progress. This view may sound like a pessimistic meta-inductivist's dream, but actually this is so only if one evaluates it from within a traditional no-miracles kind of realism. Naturalised realism highlights some of the limitations of dealing with issues of realism in a traditional 'no-miracles' (Putnam 1975, 73), or 'explanationist' (Stanford 2006, 6), context within which approximate truth is presented as the reason for the success of science. Specifically it is shown here that one of the most notable recent attacks on explanationist realism, namely Kyle Stanford's new induction argument, is powerful specifically because he works within explanationist assumptions. Naturalised realism turns on a complex evolutionary view of scientific progress within which Stanford's anti-realist threats are disarmed, not only because of approaching such threats in non-explanationist terms, but mainly because ‘explanationism’ and Stanford’s ‘epistemic instrumentalism’ are shown to be just two positions among many on a constantly evolving continuum of options between instrumentalism and realism.

The article is set out as follows: In section 2 the framework of the current realist/anti-realist debate is briefly set out. This section does not give a full evaluation of explanationism (or of other versions of realism) or even of possible explanationist answers to naturalised realism. The focus is rather on outlining points of difference between some core features of explanationism and those of naturalised realism as a *start* to outlining a *new framework for realist talk*. In section 3 the main tenets of naturalised realism are presented. By offering a novel way of looking at continuity through scientific theory change a new criterion for establishing realism is developed. It is shown that the proposed criterion for realism, called ‘evolutionary progressiveness’, giving content to a notion of ‘assembled’ rather than approximate truth, determines and constantly adjusts the status of scientific theories on a continuum between traditional instrumentalism and full blown scientific realism. This article’s objective is to alert participants in the current realist/anti-realist debate to the limitations of this debate in general by introducing an underexplored non-explanationist option. Section 4 is a brief discussion of some of the historical roots of naturalised realism. In section 5 naturalised realism is further developed in debate with Stanford’s instrumentalism. His work is discussed insofar as he is a representative of a certain line of thought in the current realist/anti-realist debate within which specifically inductive arguments ranging over the ‘mistakes’ of science, but also the under-determination of theories by data, provide constant threats to realism. The aim is to show that realism can dodge key anti-realist strategies such as Stanford’s if it is reconceived along the lines of a naturalised realism that does not rest on settling issues of approximate truth, but rather focuses on the evolutionary progressiveness of scientific theories as explanation for success and subsequently examines how evolutionary progressive theories assemble and disassemble truth. This is shown to result in unmasking the ideal of a one-size-fits-all attitude towards theories – and thus of a neat divide between instrumentalism and realism – as in fact unrealizable. The implications of the collapse of such a divide for realism are explored in section 5 by summarising the differences between Stanford’s ‘epistemic instrumentalism’ and naturalised realism.

2 The Current Context and Stanford’s New Induction

On the defense side of current realist/anti-realist debates there is most notably the ‘explanationist defense’ (Stanford 2006, 6) based on Putnam’s (1975, 73) definition of the ‘no-miracles argument’ which states that realism as characterized in terms of the (approximate) truth of scientific theories is the only explanation for the success of science that does not make the latter miraculous. One other particularly interesting line of defense is presented by various brands of so-called ‘selective realism’. Defenders of this form of realism typically separate theories into components or aspects according to some criterion such as structure or core descriptions or what have you and argue that only the selected components are eligible for realist claims, while components not thus selected (so-called ‘idle’ components) may be ‘false’ or ‘non-referring’, or simply ‘idle’ for whatever reason, without any serious implications for realism. Thus the basic strategy of ‘selective realists’ is to argue that “… only idle parts of past theories have been rejected, while truly success-generating features have been confirmed by further inquiry” (Stanford 2003b, 913).

On the ‘attack’ side of current realist/anti-realist debates the most powerful view remains so-called (1) ‘pessimistic meta-induction’ – best illustrated by Larry Laudan’s (in)famous 1981-article. The argument here is that, given the track record of science in terms of successful theories which have subsequently turned out to have been misguided or simply ‘false’, by induction, we can never trust any (successful) theory to be immune against revision or even rejection and thus success cannot after all, as realists typically try to do, be explained in terms of truth.

(2) A second line of attack is presented by the fact that data ‘under-determine’ theories. Traditionally there are two kinds of under-determination at issue – viz. ‘contrastive under-determination’ (Stanford 2009a) that states that more than one (empirically equivalent) theory can be confirmed by the same body of empirical evidence, and ‘holistic under-determination’ which focuses on the uncertainty around identifying the culprit out of a range of auxiliary and background claims in cases of failed predictions. The focus for current purposes is on contrastive under-determination which refers to the well-established fact in the history of science that – under certain conditions - more than one theory can explain the same set of data, thus implying the theories at issue to be empirically equivalent in van Fraassen’s (1980) sense of the word – and so many-to-one relations rather than neat one-to-one relations to exist between theories and ‘reality’ (or to be more precise, between theories and data sets). This leads to all kinds of concerns among philosophers of science ranging from suggestions that the notion of one independently existing ‘reality’ must after all just be some complex hoax, to suggestions that science simply cannot be about an independent reality – or, worse perhaps, science cannot be trusted, or worst of all, science is irrational – because it is not capable of either infallible or unique knowledge claims.

(3) To make matters worse, recently Stanford (2000, 2003a, 2003b, 2006, 2009b) has put on the table a third kind of under-determination namely ‘transient’ under-determination. According to this brand of under-determination there are also alternatives to current theories that are not empirically equivalent to the latter but nevertheless turn out to be confirmable “by all the actual evidence we happen to have in hand at the moment” (Stanford 2006, 17). This

kind of under-determination is ‘transient’ because it holds only while a future alternative to a current theory is still unimagined (Magnus 2006, 296) – i.e. as soon as the future alternative has been developed, the under-determination is ‘lifted’ or ‘dissolved’ as it were. This led to Stanford’s concern about ‘unconceived alternatives’ to our current theories which ultimately is a concern about our inability to identify such alternatives at the time that we offer our current theory.

This concern of unconceived alternatives grew into a third line of attack on realism which is a kind of futuristic mix of meta-induction and under-determination, namely Stanford’s ‘new induction over the history of science’, *viz.* “… we have, throughout the history of scientific inquiry and in virtually every scientific field, 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 as well confirmed by the previously available evidence as those we were inclined to accept on the strength of the evidence” (Stanford 2006, 19). Stanford offers the example of mechanical theories from Aristotelian mechanics through to the theory of relativity. In other words the claim is that in the context of theory change, theories often do not lose out to rivals but to currently-unimagined not necessarily empirically equivalent theories, of which, in future, they may turn out to be limiting cases (Magnus 2006, 296). In what follows it is shown that indeed a typical explanationist realist has almost no defense against this ‘new induction’, and it is therefore argued that the realist focus should shift from approximate truth to evolutionary progressiveness in a context of truth as assemblance as explanation for success.

The upshot of the next two sections is that traditional explanationist scientific realism has been set up to fail from the start – by its own advocates! However powerful truth may be as a criterion for realism, it cannot be presented as the *sole* explanation for the success of an enterprise as dynamic, supple and eternally self-correcting as science. Rather, here evolutionary progressiveness, as it relates to relations of reference supervening on it and as a result being responsible for ‘assembling’ truth, is offered as explanation for success. A first step to showing this is to emphasise that the fluidity of science is the result of science moving according to different degrees of continuity. In the next section only four such degrees of continuity are discussed, but that is already sufficient to illustrate the complexity of the notion of scientific continuity. The subsequent sections of the article unpack how naturalised realism can make better sense of the various guises of scientific continuity than explanationism can, without falling prey to anti-realist attacks such as Stanford’s.

3 Naturalised Realism[i]

Scientific realism, however admirable, remains a difficult doctrine to uphold. Confirmation is not as simple as some may have supposed and truth seems no more than a slippery mirage, but, on the other hand, science *is* respectable, knowledge accumulates, and rationality lingers. The challenge is how to show these claims against the odds that seem to point nowhere else than to whatever brand of anti-realism you prefer. Realism is a reflection on the nature of the products and processes of science. Science, however, is not in the business of fixed, un-revisable, or infallible knowledge, although it *is* in the business of honestly portraying aspects of reality as best or accurately it can. The latter fact implies that science remains a valid knowledge enterprise, while the former fact implies that realism, in order to honestly establish the status of scientific knowledge, *must be as self-correcting and dynamic as science is*.

Before we consider what (non-standard) kind of realism would be able to satisfy the above, let us pause to ensure we understand at least some of the actual nuances of the course of science. This is important, because, as pointed out in the Introduction, one of the main problems with traditional scientific realism is that it cannot always do full justice to the actual history of science, while the brand of realism offered here can do that, because of how it characterises the complexity of scientific continuity and because the criterion it offers for measuring the status of science's claims captures this complexity.

Consider now four possible patterns of development or movement in science which, at least at a philosophical level, already illustrate that the course of science moves according to different degrees or rhythms of continuity. (1) Inter-paradigmatic 'collaborative' continuity – here the emphasis is on cases where there is more than one paradigm at work from within which the same aspect of reality is being investigated during the same period of time, i.e. at any given time, there may be a plurality of 'paradigms' informing different descriptions of the same aspect of reality. Think for instance of research based on different aspects of cathode rays - a wide selection of people worked on different aspects of this phenomenon – the Curies, Röntgen, Villard, Thomson, Rutherford, Einstein, and these different investigations led to different 'discoveries', i.e. X-rays, the existence of radium, the phenomenon of radio-activity, Rutherford's discovery of neutrons and his description of the structure of an atom, Bohr's atomic model, and many others. Another example is the different views contributing to the acceptance of plate tectonics (e.g. Wilson 1968; Hallum 1973).

(2) 'Disjointed' continuity, or 'benign discontinuity' – Consider here the following examples: In the final instance, Priestley put Lavoisier on the track of oxygen as it were, although he himself never let go of his belief in the notion of phlogiston, physicists such as Larmor and FitzGerald did valuable work to further quantum research, although

---

[i] Parts of the discussion in this section have appeared in an earlier form in Ruttkamp (2011).

they never let go of the relation they saw between atoms (matter) and ether – in other words, even different perspectives that remain different can be cross-informative. Note that 'deletions' (i.e. 'misguided' theories) are thus meaningful for scientific work, as are instances of 'non-reference' (i.e. 'mismatched' representations), because there is still a kind of heuristic continuity of process at issue. In the case of phlogiston for instance, 'phlogiston' may not refer to anything in reality, but the research done around it led – definitely at least at an heuristic level - to the discovery of oxygen, and thus the theory of phlogiston – however 'misguided' - had an important role to play in the history of science.

(3) 'Preservative' continuity – here the focus is on the instances in the history of science where a kind of retention of knowledge of some of the properties and dynamics of a particular phenomenon may be identified. Even if some of the properties of the phenomenon had to be rejected or severely revised through the course of science, some remained relatively intact – at least in intended meaning or understanding, if not linguistically. Think for instance of the various guises of 'luminiferous aether' – for instance, in Maxwell's model of 1861-2 in terms of "vortices and rolling particles" the ether consists of more than one constituent (Whittaker 1951, 292); in FitzGerald's 1885 model wheels played the role that rolling particles played in Maxwell's model (ibid.); there were models of the ether based on 'vortex motion' (based on Helmholtz's research on vortex rings in a perfect fluid), such as Thomson and FitzGerald's model of the ether as a vortex sponge (Whittaker 1951, 293-295); at the close of the 19th century under the influence of Larmor the ether was portrayed as "an immaterial medium, *sui generis*, not composed of identifiable elements having definite locations in absolute space" (Whittaker 1951, 303); while Lorentz's ether was such that "no part of the aether can be in motion relative to any other part …an aether is simply space endowed with certain dynamical properties" (Whittaker 1951, 393), etc. Thus although there has been development in the descriptions of properties of the elastic medium that (among other things) allows light to travel, this development may suggest a kind of (spiraling) selective accumulation of information rather than stark discontinuity.

(4) 'Inconsistent' continuity – I think here of contemporary physics. There may be 'continuity' as a kind of heuristic 'cross-informativeness' even in cases of incompatible investigations of the same aspect of reality; for instance the separate work done by Thomson, Lorentz, Bohr, Millikan and others, all contributed valuable information about the charge, mass, and behaviour of electrons, although these physicists did not hold compatible views of the electron.

Of course there could be – and is - debate about the actual degrees of continuity at issue in the above examples. For instance, there is debate about whether the cases of phlogiston and oxygen are disjointed or preservative (see e.g. Kitcher 1978, 1993; Ladyman 2011; and Psillos 1997), and also about whether the cases of luminiferous ether and electromagnetic field are preservative or disjointed (see e.g. Psilos 1999, Doppelt 2007); and think also for instance of debates about the actual level of accumulation in the different depictions of genes through the development of the concept (e.g. Kitcher 1982, Vicedo 2000). Rather than refuting any plea for recognising the different ways in which science may be said to be continuous, this emphasises the fact that continuity is a many-faceted and complex issue. This characteristic of the course of science implies that *any linear depiction of the course of science and its processes is inappropriate*.

A very important feature of scientific progressiveness becomes evident here: It is surely important in order to do justice to the history of science, to understand *why* and *how* scientific theories progress, and not just *that* they do. *To know this depends just as much on the parts of theories that are 'adapted' or 'rejected' through the course of science than on the parts that are 'preserved'*. In other words, the set of scientific claims representing our 'total' knowledge of a real system at a certain time, progresses because the system of knowledge available to us becomes more and more refined as we learn from our mistakes and *adapt* our theories such that we *show how our theories can accommodate revision*.[ii] *And it is this 'evolutionary progressiveness' which realism must test and which becomes the criterion for realism as it gives content to assembled truth, rather than focusing on relations of 'approximate truth' between <u>individual</u> theories and aspects of reality <u>one at a time</u>*. It will be argued below that evolutionary progressive theories assemble scientific knowledge throughout the course of science, and that realist claims range over *series* of such theories rather than making static claims concerning individual theories frozen in time.

Now, as may be clear from the four degrees of continuity discussed above, part of understanding this notion of 'evolutionary progressiveness' is accepting the possibility of multiple descriptions of one aspect of reality through the history of its scientific investigation. These descriptions may either be refinements of previous descriptions, or descriptions of the same aspect of reality under investigation from within other (compatible or incompatible) paradigms. The goal here is to devise a form of realism that can include, or at least take note of, or consider, *all* such descriptions or explanations, rather than just acting from the viewpoint of *one* of these. Taken very broadly, science basically consists of a series of processes in which an aspect of reality is studied according to particular theories (and all their 'background baggage') that describe and explain the relevant aspect of reality 'adequately' or 'successfully' at the time. Then, in time, some theories evolve according to – among other factors not at issue now - changes at the empirical level of science, which enables them to offer more refined descriptions, conciliations

[ii] This idea is also found in belief revision of the AGM kind (e.g. Alchourron, Gärdenfors & Makinson 1985, Gärdenfors 1990), and perhaps even in some versions of semantic information theory (Shannon 1948, Carnap & Bar-Hillel 1952).

between conflicting evidence, or more detailed explanations of the particular aspect of reality, and so on and so on. Such processes affect a *complex network of theories* in a specific field of investigation, which are all connected – however weakly - and all impact on each other.

Even in cases of 'discontinuity' there is mutual impact in at least two senses. First, individual theories that fail to 'evolve' or 'cannot keep up with' the empirical side of science, also help shape these networks of theories because they show us where we went 'wrong' and in that sense 'direct' future theory change by indicating adaptations needed. And second, descriptions of the same aspect of reality from within different, possibly incompatible, paradigms also help shape these networks. And it is networks such as these that are taken into account when deciding on the evolutionary progressiveness of theories. Thus, in these terms, science is a continuously unfolding enterprise – always dynamically self-revising, having the ability to turn back unto itself, and carefully making clear the limits of its accuracy, while simultaneously striving for the highest degree of precision attainable at the time. In such a context evolutionary progressiveness offers a tool to investigate and fully appreciate the history of interlaced movements relating to the question of more appropriate or adequate levels of adaptation (to instruments, data, anomalies, other theories, etc.).[iii]

Before the nature and role of 'evolutionary progressiveness' in naturalised realism is unpacked, consider a brief housekeeping note on the kind of 'evolution' at issue here. 'Evolutionary' is meant here in analogy to Darwin's sense of 'evolution', thus not goal-directed evolution such as can be found in Lamarck for instance, but evolution according to the current environment – "… small, isotropic, non-directional variation … relentless accumulation of tiny changes through immense time… " (Gould 2002, 94). Thus, in these terms scientific progress is portrayed as a non-linear movement *according to* current empirical constraints (such as state of the art of technology and apparatus, methods of data interpretation, standard of background theories, etc.), rather than a linear movement *towards* some fixed goal. Perhaps the best characterisation of this interpretation of evolution in philosophy of science is offered by Kuhn (1996, 171ff.).

In terms of 'progress', it must be noted that discussions of progress in science focus on different aspects of the scientific enterprise. One of the most well-known trends in a realist context is to focus analyses of progress on analyses of success. However, it is worthwhile to note that success in science is a complex notion that comes in various formats – empirical success, mathematical tractability, blending in with background theory, etc. (see e.g. Leplin 2004). More importantly though, the view expounded here implies that progress is actually the result of

---

[iii] This history is actually a history of theoretical-empirical interactions that have mutual impact on each other, but in what follows the focus is on how changes at the empirical level impact on the theoretical level.

consistent revision, of cutting away certain aspects of theories according to on-going empirical outcomes of experimental work (among other factors), rather than just being the result of retaining what is 'approximately true'. Success is the result of continuous revision at various fronts of science, not just the static realisation of some metaphysical goal, or a question of "instant rationality" (Hacking 1981, 132) as suggested in critical rationalist contexts. Thus, in this context what is most seductive about the notion of evolution are 1) the idea of never-ending infinitesimal adaptation, and the result of such adaptation being the generation of more complex – more nuanced, refined – forms of whatever is doing the adapting – scientific theories in this case; as well as 2) the idea that evolution is not a teleological movement but rather movement according to current environment. And these are the features of evolution included in the analogy offered here.

One reason why 'evolution' is not used here as an overarching metaphor, is a sensitivity and openness to other features of science that fall outside the metaphor of evolution. Someone like Popper (e.g. 1981) for instance, does not really comment on the role that a notion such as Whewell's consilience plays in the course of science, while here consilience is part of recognising the complexity of scientific continuity, *viz*. the notions of disjointed or inconsistent continuity mentioned above. While there is thus agreement with someone like Toulmin (1972) - e.g. it is agreed that 'field-dependent' and 'field-invariant' elements of concepts must be separated very carefully - rather than entering into the 'absolutist'/'relativist', or the scientific rationality debate, the focus is much more specific here. Moreover, the use of some of the features of evolution is narrower in scope than in Toulmin's case, e.g. his 'forum of competitions' is naturally part of the emphasis in this account of realism on continuous adaptation of theories according to the current empirical situation, so that 'selection' isn't really a feature of evolution highlighted on its own here.

Returning now to the discussion of evolutionary progressiveness as criterion for realism, note that, as may have been expected from the above account of the complexity of continuity in science, there is no absolute standard for evolutionary progressiveness, i.e. theories do not always adapt or progress in the same way, or to the same degree, mainly because this movement of adaptation takes place according to current data and other background circumstances rather than being a simple linear movement towards some kind of goal. However, evolutionary progressiveness can be measured in a consistent manner, even if it is not possible to predict beforehand what exactly the content of the process of adaptation at issue will be. Broadly 'evolutionary progressiveness' means the following: A theory T is evolutionary progressive at time t_n iff 1) it *satisfies empirical criteria* determined by t_n-state of the art experiments, empirical instruments and apparatus, data interpretation methods, and background theories (i.e. it is empirically adequate according to empirical practices in the area of investigation at time t_n) *in such a way* that previous versions of theory T, in order to affect this satisfaction, have been adapted in significant ways, AND 2) theory T *causally refers* to relevant phenomena by virtue of the experimental situation at t_n (i.e. T's theoretical terms have been adapted such that they refer to unobservable entities that are taken to be the causes of phenomena that are observable according to empirical practices in place at t_n).

It is undeniable that relations among scientific theories and aspects of real systems are best described in the first instance by relations of empirical adequacy in van Fraassen's (1980, 4) terms: "… a scientific theory … 'saves' the phenomena, that is, [it] correctly describes what is observable". But, in the second instance, going much further than van Fraassen, the claim here is that these relations may come to be described in time also by relations of causal reference that are based on theoretical conceptualisations of relations of empirical adequacy and that cover also unobservable phenomena. In these terms, there is nothing metaphysical (in the negative or speculative positivist sense of the word) about reference. Reference is determined via the best current causal theory available – which is best based on Psillos's causal-descriptive theory of reference (Psillos 1999, Chapter 12). However, in order to capture the different degrees of continuity discussed above, and to explain their working adequately, naturalised realist claims are never based on just one relation of reference. Rather such claims range over all available relations of reference contained by all available theories networking to investigate the same aspect of reality over time, because the evolutionary progressiveness displayed by such networks offers the most refined depiction of the real system at issue possible at the time. In other words *all* available accounts of some aspect of reality impacting on each other to various degrees (as discussed above) determine the kind or quality of reference effected by the network of these accounts which, in its turn, effects the progress made at any given time. Thus measuring evolutionary progressiveness implies measuring 'reference' in the sense of measuring how theories and observable and unobservable aspects of reality *interact* in terms of current empirical developments, rather than either simply measuring to what extent our theories 'represent', or 'picture', unobservable aspects of reality, or measuring how our theories manipulate unobservable entities without checking the result of such manipulation on the theories at issue.

In these terms if one follows Tarski in believing that truth is not a property of sentences, but rather a relation in which sentences stand to the world, truth is turned into a functional notion which is about establishing evidence for realist claims. In naturalised realism such evidence is established via an adequate account of (causal) reference supervening on the evolutionary progressiveness of the theories at issue. Truth in these terms is an *understanding one comes to while establishing a specific kind of relation – one of reference – between whatever is being investigated, and the (empirical and theoretical) terms in a scientific theory.* Thus truth *is* unfolding reference in the sense that aspects of reality are 'disclosed' or 'revealed' in different ways as referential relations are refined in an evolutionary manner according to the investigation of a given aspect of reality as this investigation progresses. Truth and reference are therefore inescapably connected in the sense that reference is the mechanism that determines truth. This view is close to Peirce's substitution of truth with method, although the naturalised realist does not agree with Peirce's subsequent conclusion that all applications of this (objective scientific) method converge onto something akin to 'The Truth'. [iv]

Truth is assembled as science progresses through revisions and confirmations.[v] Thus, underlying all that has been said above in terms of networks of theories, shades of continuity, and science as product of the tension between limits of precision and striving for the highest possible accuracy, is a notion of truth as *assemblance*[vi]. As science interacts with the world, the *justification* for our beliefs in its theories deepens according to the evolutionary progressiveness of such theories which is the result of such interaction. Truth is assembled as reference relations, informed by the evolutionary progressiveness of the theories they link to reality, continuously reveal reality to us through the course of science. And sometimes, as for example in the case of disjointed continuity set out above, truth is disassembled and re-assembled into different patterns as suggested by our best (always continuously revised) explanatory theories.

This may sound very relativist. On one level it is impossible on a naturalised account of science to have an account of truth that is different in type or nature from the account of science presented. In other words, self-correction as core characteristic of science has certain implications for what truth is. Thus, in a sense, naturalised realism demands that truth as assemblance be relative to the best methods science currently has on offer for examining reality, and also relative to the quality of empirical evidence that we currently have and how we interpret that evidence via our best current theories. In another sense though, this account of truth is not relativist, because the methods and results of science are universally valid and applicable to all phenomena, organisms or processes of the same nature under the same circumstances and influenced by the same factors.

In a naturalised realist account truth then becomes (the result of) a dynamic process of relation-building rather than a (static) property of sentences, because what is of interest to naturalised realists is the mechanism that effects the unveiling of 'truths' to various degrees - and that tells us better of what is that it is - at various times. And here it is argued that this mechanism is the evolutionary progressiveness of theories as portrayed by relations of reference

---

[iv] See also Putnam (1981) to understand the sentiments driving the naturalised realist's non-representational notion of truth-as-reference.
[v] And so, perhaps all that can be said of truth is that it is sincere and accurate (*viz*. Williams 2002).
[vi] 'Assemblance' meaning 'the state of being gathered or collected'.

supervening on it. The point is that naturalised realists never 'believe' in the existence of unobservable or inaccessible entities *tout court*. Rather they build up their beliefs in such entities over time, slowly, taking into account 'mistakes' as well as 'successes', piecing together aspects of these entities. This implies that we can justifiably believe those constituents of theories that have been revised to various degrees or that have remained unrevised in the face of change at the empirical level (i.e. change in type or degree of evidence). Now some of you will say, 'oh so now we are to have *degrees* of belief, and what could that possibly mean'? It simply means what 'belief' always means, which is that it is based on available evidence. The fact that those beliefs may have to be rejected at some point, or may become more firmly entrenched or refined (perhaps due to input from other beliefs), is a matter of history and of the nature of scientific knowledge, nothing more. Moreover as long as 'available evidence' is a dynamic notion - as it is in science, as illustrated above in the discussion of the complexity of continuity in science - revision of belief will be required.

It should be clear by now that naturalised realism – and its notion of assembled truth - rest quite heavily on a conception of knowledge and of scientific knowledge in particular, that is fallibilist. Basically, fallibilism is the view that "no beliefs … can be rationally supported or justified in a conclusive way" (Hetherington 2005). There are many debates about the viability of fallibilism as an epistemological thesis (e.g. Rescher 1980, Nisbett & Ross 1980, Feldman 1981, Kahneman, Slovic & Tversky 1982, Nagel 1986, Miller 1994, Reed 2002) but the focus here is not an analysis of the virtues of fallibilism. Rather for current purposes, what is notable is that the naturalised realist views the problem of realism in science as one of the best ways in which to illustrate a solution to the classic problem of fallibilism - namely how to address the implied paradox in speaking of fallible knowledge and justification in one breath. The answer lies in interpreting truth in terms of warranted assertability, and acknowledging that knowledge is not absolute, while making sure the means of justification are as objective as possible (experiments are public and repeatable - *viz*. Peirce 1955).

Naturalised realism offers an informed way to "thread a course between the rock of fallibilism and the whirlpool of scepticism" (Lewis 1996, 566) because it at least shares Lewis' (1996, 550-551) sentiment that epistemic contextualism must somehow be taken account of when addressing the discomfort one feels in uttering what Rysiew (2001) terms concessive knowledge attributions, which are sentences of the form "'*S* knows that *p*, but it is possible that *q*' (where *q* entails not-*p*)" (Dougherty & Rysiew 2009, 123). In its pure form epistemic contextualism (e.g. Schiffer 1996, Kornblith 2000, Stanley 2004, Schaffer 2004, Weiner 2005, Greco 2008, Rysiew 2011) implies that belief depends on the "knowledge *attributor(s)'* psychology and/or conversational-practical situation" (Rysiew 2011), but for the purposes of the account of realism offered here, this condition is adapted to roughly state that whether or not a statement becomes – or more importantly, remains - a belief, depends not on the context within which the statement is made originally so much, as on the contexts within which the statement is evaluated through the course of the history of science.

Thus, naturalised realism is about truth as warranted belief and thus about the quality of justification of, and evidence for, our beliefs. Realist beliefs are determined by the context from within which philosophers of science evaluate investigations of one aspect of reality over time. This does not mean that we can never "be in a position to legitimately claim that science has achieved theoretical truth" (Psillos 1999, xx), but it does mean that the content of our truth claims – and thus what exactly is assembled as 'true' at any time - may change according to other changes in the scaffolding of science – which is perfectly in line with epistemic contextualism (Rysiew 2011). *Scepticism is a possibility only if science is depicted in static terms, and naturalised realists consistently emphasise the dynamic fluidity of science. Meaningless relativism is a possibility only if it is not made clear that belief is dependent on evidence which can be rationally articulated and made manifest.* The claim here is precisely that knowledge claims through the history of science must be constantly evaluated and re-evaluated according to newest empirical (and accompanying theoretical) data and this, in turn, implies that what can rationally be believed are knowledge claims whose revision – or (in ideal cases) perseverance in the face of changed empirical and background situations – can be made sense of throughout the history of science. In other words, the impact of revisions (as the result of empirical testing) becomes part of how we view the processes and progress of science and, in a sense, the fallibility of science's claims becomes science's greatest strength because science can state its limits of accuracy which surely makes it infinitely more trustworthy than an enterprise that pretends to have no such limits. (See also section 4 on the roots of naturalised realism.)

Note that the direction and the intensity of the progress of science are thus determined by something more than simply 'doing well in a *contingent* environment'. While versions of approximate truth such as those offered for instance by Popper (1989), Boyd (1990), Niiniluoto (1987), and Oddie (1986) also acknowledge the fallibility of science, evolutionary progressiveness does more. It highlights fallibility as the flipside of the crucial notion of dynamic self-correction in the sense that the evolution at issue here is not one that is directed towards an attractor such as 'truth' or 'theoretical correctness', but rather *an evolution following the contours of current empirical investigations, i.e. an evolution that interfaces with reality revealed through empirical (and subsequent theoretical) disclosure in a continuous manner*. Moreover it throws out representational truth and instead suggests a dynamic notion of truth that simply is the processes of science in a manner reminiscent of Peirce (1955) – and even Putnam (1981). Thus *the nature and intensity of scientific progress is determined as science interacts with its target system* *according to the empirical situation or context of this system*, and so the course of science is not necessarily lateral or linear convergent movement. This does not mean that realism collapses into irrationality, because naturalised realism offers a rational way to 'track' evidence of progress by 'measuring' how theories adapt to reality as the result of interfacing with empirical development by means of empirical adequacy and causal reference – i.e. evolutionary progression. This is the sense in which this form of realism is a 'naturalised' realism rather than a 'metaphysical' one: naturalised realism 'tracks' how science *interacts with* reality, rather than how it *advances towards* approximate truth.

Moreover, in addition, the definition of evolutionary progressiveness presented here, as well as the notion of assembled truth it gives content to, imply that traditional instrumentalism and realism lie on a continuum of progressiveness. Viewed from the present, current theories may be no more than tools in the instrumentalist sense of the word, but considered or evaluated over periods of time, they may, as part of the shifting network of theories investigating reality, come to tell entire stories of series of interlaced interactions with entities, phenomena, or events. And it seems that a view such as Stanford's epistemic instrumentalism for instance, simply fits in somewhere on this continuum (see the next sections).

Finally, a brief summary of the revised form of realism advocated here: The core ideas behind it are: (1) Scientific knowledge is tentative in the positive sense that it is continuously in a state of evolutionary renewal and refinement. (2) Science reaches out to systems in reality in myriad ways. (3) Realism is as dynamic as science is, because its verdicts are generated by evaluating a continuously evolving self-corrective enterprise. (4) Any realist depiction of science must not only reflect the fact that a theory is evolutionary progressive, but also the reasons for the evolution, which implies that the network of different theoretical descriptions of the real system at issue are considered, and not just a single theory's relation to reality. (5) A realist claim is most reliable if its evaluation ranges over *the sum* (or network) of all available (compatible and incompatible) scientific interactions with a specific real system (expressed in terms of the descriptions and explanations contained in scientific theories) taken *over as long a period as possible*. (6) The notion of truth at issue in realism is a relationary notion of assembled truth, which is the result of how reality is revealed by relations of reference supervening on the evolutionary progressiveness of the theories at issue.

Let us now first, before applying naturalised realism to Stanford's epistemic instrumentalism, pause a moment to reflect on some of the historical roots of naturalised realism in the next section.

4 The Roots of Naturalised Realism

This is a brief summary of some of the historical roots of naturalised realism which is also intended to cast more light on the notion of assembled truth introduced in the previous section. The impact of naturalised realism may be easier to understand if some preliminary remarks are made about agreements and disagreements between at least naturalised realism and critical rationalism, and between naturalised realism and the methodology of scientific research programmes. Let us first turn to the former.

The roots for the fallibilism inherent in naturalised realism lie in Peirce and in Popper's writings. This is so for many reasons, but for our purposes here, perhaps most notably, because both Peirce and Popper ascribed much importance to the notion of evolution in their considerations of scientific knowledge and method, just as the naturalised realist does. Neither Popper (nor Peirce) nor the naturalised realist demands certainty from science (e.g. Popper 1983, 144, Peirce 1955). Naturalised realism takes up Popper's (1983, 137) insistence that the "distinguishing characteristic of empirical statements [is] their susceptibility to revision". But, it is in what we *learn from falsifications* that the naturalised realist is specifically interested, both because of the fact that science's self-corrective method expands or refines our knowledge, and because of the fact that this knowledge is indeed taken to be about "something we never made" (ibid., 167).

Naturalised realism is an instance of applying Popper's critical rationalism to scientific realism – thus working out Popper's (1989) 'common sense' realism but now in *non-explanationist* detail - which necessitates magnification of how hypotheses are adapted or revised, rather than 'stopping' with a critical rationalist emphasis on testing of hypotheses. This is not meant to imply that Popper does not discuss revising of hypotheses because he does, most notably perhaps in terms of the *ad hoc* vs. auxiliary hypotheses debates. Rather, what is meant is that naturalised realism identifies as crucial to the scientific enterprise the resilience of science, i.e. the ability of science to revise itself, to adapt its theories according to the outcome of experiments, and wants to zoom in on this ability. Thus, while the naturalised realist agrees with the critical rationalist that theories must be tested in order to check how well they stand up to demands from the experimental and empirical world, the former is most interested in how the theory 'reacts' to such demands. As critical rationalists take hypotheses as given, in the sense of not dwelling on the formulation of hypotheses, and rather emphasises its testing; so the naturalised realist takes the testing for granted, but emphasises adapting to the results of tests.

Thus rather than emphasising progress in terms of the boldness of a theory and instant immanent refutation by crucial experiments, the naturalised realist flips the coin and emphasises progress in terms of the ability of theories to adapt according to the current experimental (and theoretical) context throughout the investigation of a certain aspect of reality. This shift of focus is the result of naturalised realism not being about checking the representational powers of science, but rather being about analysing the level of *interaction* between theories and experimental results – how must theories be adapted to current experimental results, and how does such evolutionary progressiveness impact on further experiments in return - more than anything else. (This is picked up again below in the discussion on Lakatos' methodology of science.)

To summarise, testing is as important to a naturalised realist as to a critical rationalist (or to an advocate of Peirce's method of science, for that matter), but the naturalised realist, being a realist, is most interested in the reactions of theories or hypotheses to tests and the resulting implications of such reactions for hoped-for links between theories and the empirical world which must surely be accepted as being fluid links, rather than static ones. And determining what it could mean to describe a link as 'fluid' is a huge part of the naturalised realist project. This reminds of how Peirce's fallibilism linked with his '*tychism*' (Greek word for 'chance' or 'luck' – see Burch 2010, 13-16). According to Peirce's non-deterministic account of the universe "… nature is not a static world of unswerwing law but rather a dynamic and dicey world of evolved and continually evolving habits that directly exhibit considerable spontaneity" (ibid., 15). Burch (2010, 12) points out that Peirce's "… fallibilism is obviously connected with the fact that science is not shooting at a fixed target but rather at one that is always moving". This highlights the 'naturalised' aspect of naturalised realism – nature's evolutionary characteristics must be taken into consideration by scientific method, reflected in scientific knowledge, and must then, in turn, surely be acknowledged by any philosophy of science, specifically perhaps of the realist kind. The self-correcting nature of scientific method is thus directly responsible for the fallibilistic epistemology espoused by naturalised realists, as Peirce's evolutionary beliefs and his *tychism* were responsible for his fallibilism.

In terms of truth though, the naturalised realist parts ways with the critical rationalist more seriously. The naturalised realist does not agree that the best way to depict truth in science is to state that "… the best we can realistically hope for is to approach the truth gradually along a chain of better and better approximations" (Miller 1983, 17). In naturalised realism, there is no linearity in investigating truth in science and no convergence (and thus no approximation in this sense), rather there is continuous adapting according to continuously shifting 'current' (empirical and other background) criteria as the result of continuous objective tests. That this is still rational advancement lies in the naturalised realist defence of its 'subjectivist' move to depict truth as justified belief. Popper strongly takes position against subjectivist epistemologies, as did Peirce before him, so let us briefly consider the naturalised realist's position. Burch (2010, 19) writes in this context that "Peirce suggested that any justifiable use of subjectivism in connection with probability theory must ultimately rest on quantities obtained by means of objectivist understanding of probability". In the same manner the naturalised realist 'subjectivist' depiction of truth as justified belief rests on the 'objective' assembling of truth according to empirical testing and evolutionary progressiveness.

Thus, what is suggested, is a kind of mid-way between 'subjective' and 'objective' epistemologies – the subjective nature of truth-as-warranted belief is tempered in naturalised realism by the objectiveness of the results of the process of assembling truth given by the fact that this process can be criticised and revised just as the processes of science can be criticised and revised. Thus, like Peirce in a sense, the naturalised realist equates truth with method (and is here closer to Putnam (1981) perhaps than to Popper), but instead of going the converging route as Peirce does or the approximation one as Popper does, the naturalised realist affects this equation by turning truth into a functional pragmatic non-representational notion and balancing the possible subjective undertones of assembled truth as warranted belief with the Peircean and Popperian insistence on public empirical testing, and, in addition, emphasising evolutionary progressiveness as a rational criterion for progress.

This must surely remind the reader of Lakatos – specifically of Hacking's (1981, 129) point that "Lakatos's problem is to provide a theory of objectivity without a representational theory of truth". The problem that Lakatos had – which is one that an account of naturalised realism also has – is what Hacking (1981, 130) calls the "…common English-speaking attitude … that knowledge is growing just if we are getting at more of the truth. …that truth is conceived of as fixed, while knowledge is to be defined as that which gets at this pre-existent truth. Hence in English philosophy knowledge is to be characterised externally, in terms of how well it represents reality". Neither Lakatos, nor the naturalised realist, is primarily concerned with the issue of representation or with a correspondence theory of truth though. Now, Hacking (ibid., 131) points out that the result of the Kantian divorce of truth from representation is the problem of distinguishing between "the objective … [and] the merely subjective if we are not allowed to say what objective truth represents …" (ibid.). We know that Peirce's (objective) surrogate for truth was methodology (ibid.), and Hacking (ibid.) views "Lakatos's methodology as a sophisticated and historicised version of Peirce's logic of inquiry" – and, as implied often above, it is the intention of the naturalised realist to continue this tradition by ensuring that what is presented as 'truth' in science, truly is a reflection of the methods science used to produce what is being evaluated.

Thus, with Peirce and Lakatos, the naturalised realist fights to substitute truth as representation with "process" (Hacking 1983, 113), i.e. the processes of science, the growth of scientific knowledge. Lakatos was not interested in rescuing truth at all (*viz.* Hacking 1983, 119), but he did want to rescue objectivity in science (as Peirce did) – he did that not by turning to alternative accounts of truth, but by making the point that "… we can comprehend the objectivity of our present beliefs by reconstructing how we got there" (ibid.), and we start by analysing the growth of knowledge in terms of historicising the course of science. Thus the naturalised realist's insistence on the fact that progress can still be rationally traced and articulated (even though assembled truth can be no more than warranted assertability) because of the necessity of theories having the ability to satisfy objective public empirical demands is also much in line with Lakatos's sentiments against representational truth while rescuing objective science.

Staying with Lakatos and in conclusion of this section, briefly some remarks on research programmes, and then, most importantly, on the retrospective character of Lakatos' methodology. First, the naturalised realist follows Lakatos (1978, 34) when she insists on series of theories as the unit for determining the status of scientific knowledge. Larvor (1998, 51) remarks that for Lakatos "… what makes for scientific respectability is the manner in which one develops and nurtures a cluster of thoughts over time, rather than any purely logical feature". And, in order to effect such development, we need "a unit of scientific appraisal which can maintain its identity as it changes. Lakatos's suggestion … is the 'research programme'. In his sense, a research programme is the sum of the various stages through which a leading idea passes". In this sense research programmes is an example of naturalised realist networks in the sense that 1) they consist of series of theories, and in the sense of 2) the insistence that progress can only be determined over time. These ideas of historicising the course of science and actually using it honestly to evaluate the status of theories are very important to the naturalised realist too.

As a final point of discussion of Lakatos's philosophy of science consider the important fact that Lakatos's methodology, in the sense of his philosophy of science, is "backward-looking" (Hacking 1981, 132) – as naturalised realism is. All that is 'forward-looking' in Lakatos is the positive heuristic (or the criterion of evolutionary progressiveness in naturalised realist's case) but there are no general guidelines for the future progress of science of the kind which Stanford is looking for, for instance. Lakatos is against "instant rationality" (Hacking 1981, 132) and rather substitutes it with a notion of "retroactive rationality" (ibid., 133). Thus for Lakatos "… the mark of the scientist is not whether he abandons his theory in the face of a counterexample, but how he advances to the next stage of his research programme. … for Popper a theory is scientific only if its champions are prepared to abandon it when falsified. For Lakatos, an inquiry is 'scientific' if it can be written up afterwards as meeting the standards of the methodology of scientific research programmes, but a programme may be only abandoned if there is a manifestly better alternative available" (Larvor 1998, 57). The naturalised realist's insistence that realists evaluate networks of theories rather than single theories one at a time reflects support for this kind of retroactive rationality.

In a sense naturalised realism is as common-sensical as Popper's realism as it agrees with his (Popper 1983, 222) statement that while there is "… no guarantee against error … [t]he whole question of the truth and falsity of our opinions and theories clearly becomes pointless if there is no reality, only dreams or illusions". The naturalised realist takes the implications of Popper's realism further though because she honestly engages with the history of science, while it has been pointed out often that science doesn't progress according to crucial experiments. Moreover, success is not so much about formulating bold theories (based on 'guesswork'), but rather it is just as historied a concept as truth and reference are. Success is the result of hard work and is something that is worked on every day in science. It can only be retrospectively evaluated because it is the result of the quality of theories' ability to adapt to changes in experimental data (and background theories). In its turn, naturalised realism takes Lakatos's historicised explanation of the course of science further by presenting evolutionary progressiveness as a way in which choices can be made among different networks of investigations, and by building out his insight that the unit of evaluation in philosophy of science must be series of theories rather than single theories. In this sense naturalised realism is a kind of neo-combination of critical rationalism and the methodology of scientific research programmes that supersedes both these philosophies of science by marrying aspects of each philosophy to an anti-representational notion of truth that is the kaleidoscopic result of revelations made by relations of reference supervening on relations of empirical progressiveness throughout the development of investigations through the course of science.

5 Stanford's Arguments as the End of Explanationism

In this section each of Stanford's anti-realist arguments – in terms of under-determination, induction, and trusting science – will be considered. As a result, both the stalemate effect they have on the current explanationist realist debate, and how naturalised realism defuses them will be illustrated.

Turning first to under-determination: The point about traditional under-determination is that empirical evidence and how it plays out in terms of predictions and other empirical interventions (Stanford 2006, 8) are not strong enough mechanisms to guide theory choice among a set of empirically equivalent theories such that one theory is obviously the best. On the other hand, the point about Stanford's 'transient' under-determination is that (Stanford 2006, 17) "… our grounds for belief in a given theory would be no less severely challenged if we believed that there are one or more alternatives that are *not empirically equivalent to it* but are nonetheless consistent with or equally well confirmed by all of the actual evidence we happen to have in hand at the moment". The promise of the previous two sections is that neither the fact that evidence alone cannot necessarily point out an obvious best theory at a given time, nor Stanford's unconceived alternatives, necessarily herald the death of realism – if it is revamped in the sense suggested here.

To see how this promise may be realised, the idea of realists having to consult a network of interaction between science and reality needs to be unpacked a bit more: Actually, as already hinted at in the above, there is more than one such network at issue if one reflects on the processes of science. First, there are networks made up by all available (compatible and incompatible) theories studying a certain aspect of reality. Then, there are, underpinning each theory in the former kind of network, corresponding networks of reference relations at various stages of refinement between the theories at issue and the relevant aspect of reality. Then, finally, there are networks of theories depicting the different degrees of evolutionary progressiveness of each stage of a specific theory's investigation of an aspect of reality superimposed on the first kind of network on the one hand, and offering a supervening base for the networks of reference relations on the other. In this sense, the impact of the traditional under-determination arguments on claims that science is 'about' reality, is softened impressively, in the sense that through the various superimposed networks it can be acknowledged that alternative investigations of the same aspect of reality – whether compatible or not – all contribute information about that aspect of reality. In this sense, as mentioned before, the naturalised realist verdict at issue is not whether a *single* theory is 'true' of some aspect of reality, but rather whether our justification for knowledge of the aspect of reality is deepening, and finally whether our knowledge of this aspect of reality is increasing albeit in a non-convergent manner.

In the case of Stanford's transient brand of under-determination, the idea is that a given empirical 'system' or data set transiently under-determines the current accepted theory explaining it (let's call it CT) and at least one future alternative theory/explanation (let's call it FA_x). Now, as soon as FA_x has been developed into an 'actual' as opposed to a hitherto un-imagined theory, the under-determination is lifted (and CT may become known as a limiting case of FA_x). (See and compare Magnus 2006.) To expect now either of science to lift this under-determination beforehand (i.e. before the future alternative has been developed), or to expect of explanationist realists to be able to deal with this kind of under-determination, are both options that do not make sense in a naturalised realist context where the ideal is to stay as close as possible to the actual functioning of science. A naturalised realist argues that any FA_x may come into being in at least two possible ways: 1) It can be generated from CT in an evolutionary manner according to new empirical and theoretical research activity or the use of new (empirical) research methods. Instances of transient under-determination in this case are simply regarded by a naturalised realist as items in the series of investigations of the aspect of reality at issue taken up in a network tracking the evolutionary progressiveness of such investigations.[vii] In naturalised realist terms evaluating science is

---

[vii] P.D. Magnus (2006) offers an argument, based on aspects of the change from classical to relativistic mechanics, which concludes that instances of both transient under-determination and new induction are much more common

not about singling out theories in terms of approximate truth or even degrees of truth-likeness, rather it is about tracking the development of our knowledge of reality as it unfolds, or in other words, tracking the truth currently assembled. 2) A second possibility is that a FA_x comes into being based on empirical work separate from (perhaps even in another field) the empirical work supporting CT. In this case it may turn out that FA_x is incompatible to the CT at issue. The holistic approach to scientific investigations advocated by naturalised realism defuses the situation again though – or at least softens its impact - because again naturalised realism is not about singling out one theory, but rather about reflecting on all information contributed about a certain aspect of reality. Thus in this sense again FA_x will be taken up in a network – in this instance the network of all (compatible and incompatible) scientific interactions with the aspect of reality at issue. In this way the various kinds of continuity among alternatives are captured in a way not possible in explanationist forms of realism. (Another reason why transient under-determination does not make sense in a naturalised realist context is this kind of realism's retrospectiveness – but this will be picked up on later in this section.)

To recap, the main threat from under-determination is that it may turn out that science has no rational direction given that there are no obvious *immediate* empirical reasons to choose between the options on the table. The point here is not at all to minimise this threat, but to show that if the narrative of progress or the history of reference which naturalised realism demands, is the lens through which under-determination is considered, it becomes clear that what is lacking in the traditional depiction of under-determination as a threat to realism, is the acknowledgement that theories evolve through a continuum of options – and that choosing one theory above another is not what realism is about. Rather the suggestion is that realism is concerned with checking whether our knowledge about a given aspect of reality is increasing in the monotonic sense of deepening, as opposed to convergence onto something like 'truth' (compare Hacking (1983, 55-57)).

Another threat from unconceived alternatives is that even if there turns out to be some rational procedure for comparing and selecting options, scientists may – and do - still make choices that turn out to be 'false' or at least 'misguided'. But, evolutionary progressiveness basically tracks the impact of 'misguided' choices on theory development, and this is why it is okay to not know beforehand if choices will turn out to be misguided or not: The nature of science is such that it corrects its 'mistakes' and naturalised realism, through measuring evolutionary progressiveness, can reflect how those 'mistakes' have influenced the development of science rather than pretend they never happened. More on this follows later in this section.

---

place and perhaps natural in science than Stanford, at least on the face of it, seems to allow for – or *is able to allow for*, given his explanationist target.

This brings us to Stanford's inductive arguments against realism. As stated in section 2, Stanford's concern about transient under-determination grew into a line of anti-realism which is almost a perfect mix of meta-induction and under-determination, namely the 'new induction over the history of science'. Stanford, as we know, identifies the "most significant challenge to scientific realism" as "our inability to consider the full range of serious alternatives to a given hypothesis which we seek to test" (Stanford 2009b, 253). It is difficult to see *why* we need to be able to do this if everyone acknowledges that scientific knowledge is dynamic (tentative). Moreover, *how* are we supposed to accomplish this if we acknowledge the fluidity of science as well as the shortcomings of our human cognitive abilities? The anti-realist may simply state that this is precisely their point, it cannot be done. The point made here is that it does not *have to be* done.

Stanford (2009b, 256) does not think, for instance, that we should believe scientific claims "if the only reason for doing so is that [they are] … part of or follows from an empirically successful scientific theory …", but … why not? The reasons are not necessarily the explanationist ones that Stanford expects, thus that the theory is approximately true, or that we can guarantee it to be successful forever; but rather, we can indeed 'believe' scientific claims in such a context, because the nature of science is such that claims that flow from empirically successful theories have been and will be tested and adapted throughout the course of science according to the various relations of causal reference at issue. Thus (again), the point is that within the circle of no-miracles arguments there seems to be no answer to Stanford, and hence the plea for considering breaking free of this circle of argumentation, and relying on evolutionary progressiveness constantly assembling and disassembling truth to analyse the success of science – as the moving target that it is - rather than relying on the linear image of scientific processes implied or suggested by approximate truth. Naturalised realists consider the network of scientific interactions between theories and a relevant real system over time effecting deeper and deeper layers of reference through processes of evolutionary progressiveness, all the while acknowledging or being aware of the tentativeness of their own evaluations. After all, how can an inconclusive, fallible enterprise such as science be evaluated or described by a philosophy of science that is fixed and non-revisable?

Briefly consider some remarks made by Michael Devitt (2011) on Stanford's account of unconceived alternatives to show even more clearly why it is flawed from the point of view of the arguments expounded above. Devitt (2011) makes the point that the real danger in both the traditional pessimistic meta-induction and the unconceived alternatives version of it is not the premise with regards to past theories having failed to describe the unobservable world, but rather the inference from past to present theories. And, in Stanford's case, the added claim that present theories differ 'radically' from past ones, is even more crucial. In principle, Devitt (2011) disagrees that our present theories will necessarily fail as badly as our past ones in describing the unobservable world, because our methodologies for investigating unobservables have improved considerably. This is apt for the arguments made here for obvious reasons with regard to evolutionary progressiveness.

More specifically, note that the scientific realism debate is not about 'commitment to current scientific theories' in a vacuum. Rather, as often pointed out above, the debate is *informed* somehow by what happened in the past *because* the mistakes or misguided descriptions of unobservable entities informed or shaped current theories to varying degrees. Thus, neither Devitt's argument for realism nor the arguments offered here build on the success of current theories as opposed to the failure of past ones. While Devitt (1991, 2011) gives an explanation for the success of current theories via his argument for better methodologies, here one is given that focuses on the actual continually revising processes of science. The plea is for a kind of meta-continuity in the sense that past failures show us the way to present success.[viii] And, there is a sense in which we *need* the discontinuity with the past ('radically different alternatives') to understand the continuity of the present in many senses – as can be inferred from the discussion of the complex nature of the notion of continuity. Note also the support here for the naturalised realist notion of success as a 'moving target', a dynamic notion that is as 'alive' as science is, and as 'assembled' as truth is.

Finally, let us now briefly focus on Stanford's (2006, 2009b) 'trust argument' by considering two of the mechanisms by which traditional realists have tried to rescue realism in the face of meta-induction attacks – 1) calling upon causal reference (Stanford 2006, 147ff.; 2003, 555ff.), and 2) going the selective realism route (Stanford 2006, 153 ff., 2003a, 559ff.).[ix] As illustration of both these aspects of the trust problem consider Psillos' (1999) theory of reference. This is a hybrid causal-descriptivist theory in terms of which descriptions determining reference are stated in causal terms, and it is the 'kind-constitutive' properties of a posited object or magnitude which determine reference and continuity of reference through theory change (Psillos 1999, 295-297). Although Psillos' theory is probably the best available for realists at the moment, the continuity will not be as clear cut as Psillos hopes in terms of 'core constitutive properties' continuing through theory change, as it is not entirely obvious that what is core to the description of an entity, phenomenon, or event does not change as theories change. [x]

[viii] Think again of AGM belief revision.
[ix] There is a lively debate on this issue which cannot be covered here – see for instance Laudan (1984), Ladyman & Ross (2007), Doppelt (2002), Chang (2003), Lyons (2006), Votsis (2005) and many others.
[x] The naturalised realist's full account of reference cannot be unpacked here, but briefly, the argument is that the open-endedness of science in the context of referential continuity makes more sense if the emphasis is on the causal role an entity plays in virtue of an *empirically adapted* core causal description associated with the term denoting the entity.

Stanford (2003a, 556) absolutely disagrees with attempts such as Psillos' to rescue reference in 'misguided' theories for two reasons: 1) the kind of reference at issue here (e.g. 'ether' referring to 'electromagnetic field') can only be determined after the fact, and in a kind of *ad hoc* manner which Stanford regards as cheating, and 2) if even 'misguided' theories can still refer, why should we trust science? Finally here the full barrenness of the explanationist debate becomes clear – it becomes almost easy to have a checkmate situation if anti-realists demand maneuvers of explanationists that include forfeiting truth somehow.

Stanford's (2003a, 158; 2003b, 917, 2009b, 263) concern with the retrospective character of selective realism is that what selective realists typically 'save' of theories are not necessarily what scientists of the time would have saved (contra Psillos (1999)), and *vice versa*. Examples he gives typically include Maxwell's insistence on the existence of the ether to explain the propagation of light and electromagnetism and Lavoisier on the need for the caloric fluid to explain the phenomenon of heat. And worst of all to him, the "impressive retrospective convergence between our judgments and the sources of the past theory's success" (Stanford 2006, 166) "…will obtain *whether or not* the current theories we are using to assess both the accuracy of parts of past theories and the sources of those theories' success are themselves even approximately true" (Stanford 2006, 167).

This is of course all true enough, but in a sense still misses the point – in a way typical of explanationist anti-realists. The actual point is that we can only identify which features of theories are success-generating, if we understand 1) why the 'idle' parts were idle or other parts worthy of rejection and 2) how the theory or existing knowledge claims had to be adapted to make sense of rejecting certain parts of it. It is thus misguided to focus on 'success-generating' features only (and, as alluded to already, it is equally misguided to view success as static anyway). This implies: 1) there is no absolute always applicable description of 'success-generating' parts of theories (and this is in agreement with Psillos (1999) – no 'explicit' criterion for selective confirmation exists – but here the deciding factor is not the choices made by scientists at specific times as he seems to think, but rather it is the evolutionary nature of the course of science); and 2) determining which parts of theories are parts that 'endure' can be done retrospectively *only* - recall the different patterns of scientific progress and the emphasis on the impact of rejected parts of theories on defining progress mentioned in section 3.

Thus while the correct attitude to adopt towards a theory in terms of realism or instrumentalism depends on the quality, quantity and type of the available evidence in support of the theory, it is never possible – contrary to Stanford's expectations - to determine once and for all, or beforehand, which parts of a theory will be supported by available evidence through the course of science. Moreover *if* indeed it is typically those parts of theories that scientists think must be preserved that are actually changed in the end, it shows something *right* about science not something *wrong*. It shows – ironically enough - precisely that we *can* trust science, even if scientists turn out to be wrong, *because* science is self-critical, self-revising, evolutionary, and the methodology of science guarantees constant adjustment to current empirical standards as those are adapted in their turn – irrespective of scientists' own 'hunches'. And, the naturalised realist believes it is this characteristic of science that realism should be about! In other words science *can* be trusted over the long term – note that the focus is again not on individual theories – to grow and develop and eliminate mistakes and to be honest about what it can and cannot do. Thus, it can be trusted to always give the best answer according to current quality of evidence, but it is misguided to expect it to always give the full 'right' answer or even part of the right answer instantly.

In terms of Stanford's second concern above – i.e. why should we trust 'misguided' theories, or more to the point, why should we 'save' their reference? - it is clear that while truth cannot be divorced from reference as some advocates of causal reference seem to intend (see e.g. Hardin & Rosenberg 1982), at the same time, it is obvious that some mechanism other than, or at least in addition to, truth is needed to accommodate the fluidity of science. This is what naturalised realism offers. It offers an approach in which the evolutionary progressiveness of theories and (assembled) truth-as-causal-reference are in mutually empowering relations. Moreover, as pointed out often now, Stanford is focused on individual theories, and the argument here is that the focus should rather be on the history of science – in terms of layers of networks as discussed above - because somehow the evolutionary aspect of the methodology of science is stronger than individual scientists' insight or individual theories' impact.

In other words, Stanford's concerns are problematic only if realism is taken to be a static evaluation of an enterprise that can be finished or concluded at a certain time. There is indeed no guarantee as to *which* theoretical description will endure through change, but perhaps there is a guarantee that *some or part of* a theoretical description will, albeit in an altered, modified, or transformed manner. It may of course be difficult to see continuity if the best we have are instances of some reference, some truth, some success, and so on. At least, though, this shows precisely that continuity is *not a simple issue*, that there are different kinds of continuity, and that continuity should not be looked for in a linear format.

6 Conclusion

In what follows differences between naturalised realism and Stanford's 'epistemic instrumentalism' are briefly summarised, and this section concludes with some general remarks on the advantages of buying into the former. In the final chapter of *Exceeding our Grasp*, Stanford (2006, 194ff.) considers the problem of what precisely it is about scientific theories that can be believed in the context of facing a common point of criticism against instrumentalism, namely the question why – or whether - it is okay to 'use' parts of theories without believing in them. Based on Kitcher's (1978) account of token vs. type reference, he finally, after suggesting different options for overcoming the disadvantages of syntactic and eliminative instrumentalism, and taking into account that "… we cannot make use of our scientific theories for the pursuit of our practical endeavours without believing some part of what they say" (Stanford 2006, 197), suggests a definition for 'epistemic instrumentalism'. This definition states that "… it is open to us to believe the claims about entities, events, and phenomena that they make *as those very claims can be understood independently of the theory or theories toward which we are adopting an instrumentalist stance*" (ibid.).

But surely 'understanding' always takes place in *some* theoretical framework if not the one belonging to the theory we are approaching instrumentally. This seems weirdly circular, because what would the stance be that we adopt towards the theory in whose context we understand the claims and which we simply apply in the context of the theory we adopt an instrumentalist stance towards? And how can "a theory's concrete consequences" be "grasped independently of the theory itself" (Stanford 2006, 198)? Moreover, surely, if claims that cannot be understood in this independent way are then simply used and not believed, this is still an instance of use without belief (compare Stanford 2006, 198). The only way in which this may make sense is to recall the continuum of options between instrumentalism and traditional scientific realism referred to in section 3. Stanford at least seems to leave it open that descriptions of inaccessible entities that cannot be understood independently of the theory at issue at a given time, can, in time, come to be believed and to inform – or validate? - the use of parts of other theories that cannot yet be believed and of which it is independent, and so on.

Note that in the case of naturalised realism, what a scientist believes can also change, because what is believed will be determined by the quality of available evidence. Specifically, as noted above, naturalised realism implies that we can justifiably believe those theoretical constituents that, in the face of change at empirical level (i.e. change in type or degree of evidence), have been revised to various degrees. In this sense Stanford (2006, 205) makes an interesting point: "The difference between the realist and instrumentalist, then, is not one of global epistemic attitude towards 'theories', but rather a local difference in the specific theories each is willing to believe on the strength of the total evidence available". This sits fairly comfortably with the continuum of stances towards theories suggested by naturalised realism. He (2006, 206) further claims that the difference in epistemic position of a person who adopts an instrumentalist attitude towards science and a realist is that a realist typically "believes that the best-confirmed account we currently have of a given natural domain is (probably, approximately) true", and the realist will typically then also choose such a 'true' theory to make predictions, while it is not necessarily typical of the instrumentalist to do so. A realist will adopt an instrumentalist attitude to a theory only if there is no competing 'true' theory available.

This too, can be true of the continuum referred to above, if we adapt it a bit according to naturalised realism. A naturalised realist never has views on the truth of single theories, as to her, truth is a complex and dynamic notion which is the result of a network of reference relations all constantly 'revealing' aspects of the inaccessible domain at issue to various degrees of refinement. So the difference in epistemic position between a realist and an instrumentalist in these terms simply lies in the quality of evidence available to each. If it is early in an investigation and no network of reference relations yet exists according to which evolutionary progress can be effected, then a naturalised realist will have a traditional instrumentalist stance towards the theory at issue, and it will be the best-confirmed version of the theory available *at the time*.

Thus, rather than trying to figure out how exactly an epistemic instrumentalist will come to believe in the 'independent theory' describing the domain at issue such that she can apply the theory she does not, and realists do, believe in, and given the distrust of explanationist accounts of 'approximate truth' alluded to in this article, let us accept Stanford's points against approximate truth. Indeed 'the best presently available' does not necessarily mean 'approximately true'. And, indeed theories can simultaneously be instruments in his sense and resources for inquiry. This agreement is from a point of view that is still 'realist' though, while Stanford believes realism to have no chance of making sense. This is because he is arguing against an explanationist realism based on approximate truth, while the argument for naturalised realism is based on 'assembled truth as reference' which is a dynamic process that never ends. Neither realism nor instrumentalism has to be ditched in the process however. On a naturalised realist account rather both views are possible stances towards the status of theories on the continuum of options available through the course of scientific investigation. In a nutshell, the difference between naturalised realism and Stanford's view is thus that he agrees that the nature of science is tentative at best, but while his account of epistemic instrumentalism does not allow this to shape or impact positively on how he sees realism evaluating science, naturalised realism does.

So theories can't be literal descriptions (explanationist realisms), nor can they be merely tools for empirical interventions (instrumentalism) (see Stanford 2006, 5), because their 'lives' are simply too turbulent and the descriptions they offer, while as accurate as possible, are too limited (by factors such as the state of the art of apparatus, the framework of other theories within which they function, the evolutionary nature of the methodology of science, etc.) to be either one in any complete sense. And it is for this reason that the traditional instrumentalist-realist stand-off is collapsed here into a continuum of evolving options between the two extremes.

In general we must thus accept that scientific knowledge will typically be 'the best we have yet', but will always at the same time be open to challenge. However it is suggested in the above that we trust our theories *because* they are challengeable, not because they are invincible. Science constantly reveals reality to us in different guises, and introducing evolutionary progressiveness as realist criterion on which reference relations supervene and which assembles truth in various ways, enables us to measure how our theories adapt to reality according to what has been revealed, and thus to measure science's ability to self-correct *as the result of interacting with reality, not as the result of measuring representation*. In this way realism becomes a second-order reflective mimicking of science. Repositioning realism as advocated here allows realism to come into its own – perhaps for the first time – as an interpretation of science. This is so because naturalised realism interprets the significance of the trials *and* errors of science, rather than portraying science only as a one dimensional triumphant march towards 'the truth'.

References

Alchourron, C.E., P. Gärdenfors and D. Makinson. (1985). On the Logic of Theory Change: Partial meet contraction functions and their associated revision functions. *Journal of Symbolic Logic* 50, 510-530.

Boyd, R. (1990). Realism, conventionality, and 'realism about'. In G. Boolos (Ed.) *Meaning and method: Essays in honour of Hilary Putnam*. Cambridge: Cambridge University Press.

Burch, R. (2010). "Charles Sanders Peirce", *The Stanford Encyclopedia of Philosophy (Fall 2010 Edition)*, Edward N. Zalta (ed.), URL = <http://plato.stanford.edu/archives/fall2010/entries/peirce/>.

Carnap, R. and Y. Bar-Hillel. (1952). An Outline of a Theory of Semantic Information. *Research Laboratory of Electronics, Massachusetts Institute of Technology, Cambridge MA*.

Chang, H. (2003). Preservative Realism and its Discontents: Revisiting Caloric. *Philosophy of Science* 70, 902-912.

Devitt, M. (2011). Are Unconceived Alternatives a Problem for scientific Realism? *Journal of General Philosophy of Science*, Published online: 30 August 2011.

Devitt, M. (1991). *Realism and Truth*. Princeton: Princeton University Press.

Doppelt, G. (2002). Book Reviews: Relativism and Reality: A Contemporary Introduction. By Robert Kirk. Scientific Realism: How Science Tracks Truth. By Stathis Psillos. *The Philosophical Review* 111(1), 142-147.

Doppelt, G. (2007). 'The Value Ladenness of Scientific Knowledge'. In H. Kincaid et al (Eds.), *Value-Free Science?* Oxford Scholarship Online Monographs. Oxford: Oxford University Press.

Dougherty, T. & P. Rysiew. (2009). Fallibilism, Epistemic Possibility, and Concessive Knowledge Attributions. *Philosophy and Phenomenological Research*, LXXVIII(1), 123-132.

Feldman, R. (1981). Fallibilism and Knowing that one Knows. *The Philosophical Review*, 90(2), 266-282.

Gärdenfors, P. (1990). The Dynamic of Belief Systems: Fiundations vs. Coherence Theories. *Revue*

Internationale de Philosophie 172, 24-46.

Gould, S.J. (2002). *The Structure of Evolutionary Theory*. Cambridge MA: Belknap Press of Harvard University Press.

Greco, J. (2008). What's wrong with Contextualism?. *The Philosophical Quarterly, 58(232), 416-436.*

Hacking, I. (1981). Lakatos's Philosophy of Science. In I. Hacking (Ed.), *Scientific Revolution* (pp. 128-143). Oxford: Oxford University Press.

Hacking, I. (1983). *Representing and Intervening. Introductory Topics in the Philosophy of Natural Science*. Cambridge: Cambridge University Press.

Hallum, A. (1973). *A Revolution in the Earth Sciences. From Continental Drift to Plate Tectonics*. Oxford: Oxford University Press.

Hardin, C. and A. Rosenberg. (1982). In Defence of Convergent Realism. *Philosophy of Science* 49, 604-615.

Hetherington, S. (2005). Fallibilism. *The Internet Encyclopaedia of Philosophy (October 2005)*, URL= <http://www.iep.utm.edu/fallibil/>.

Kahneman, D., P. Slovic & A. Tversky. (Eds.) (1982). *Judgment under Uncertainty: Heuristics and Biases*. Cambridge: Cambridge University Press.

Kitcher, P. (1993). *The Advancement of Science*. *Science without Legend, Objectivity without Illusions.* Oxford: Oxford University Press.

Kitcher, P. (1982). 'Genes'. *The British Journal for the Philosophy of Science,* Volume 33(4), 337-359.

Kitcher, P. (1978). Theories, Theorists and Theoretical Change. *Philosophical Review*, 87, 519-547.

Kornblith, H. (2000). The Contextualist Evasion of Epistemology. *Philosophical Issues*, 10, 24-32.

Kuhn, T.S. (1996). (3rd Ed.) *The Structure of Scientific Revolutions*. Chicago: University of Chicago Press.

Laudan, L. (1981). A Confutation of Convergent Realism. *Philosophy of Science* 48, 19-48.

Laudan, L. (1984). Explaining the Success of Science: Beyond Epistemic Realism and Relativism. In J. Cushing et al (Eds.), *Science and Reality* (pp.83-105). Notre Dame: University of Notre Dame Press.

Ladyman, J. (2011). Structural realism versus standard scientific realism: The case of phlogiston and dephlogisticated air. *Synthese*, 180, 87-101.

Ladyman, J. and D. Ross. (2007). *Every Thing must go: Metaphysics naturalised*. Oxford: Oxford University Press.

Lakatos, I. (1978). *The Methodology of Scientific Research Programmes*. Cambridge: Cambridge University Press.

Larvor, B. (1998). *Lakatos. An Introduction*. London: Routledge.

Leplin, J. (2004). A theory's predictive Success can warrant Belief in the unobservable Entities it postulates. In C. Hitchcock (Ed.), *Contemporary Debates in Philosophy of Science* (pp.117-132). Massachusetts: Blackwell Publishing Company.

Lewis, D. (1996). Elusive Knowledge. *Australasian Journal of Philosophy*, 74, 549-567.

Lyons, T.D. (2006). Scientific Realism and the Strategema de Divide et Impera. *British Journal for the Philosophy of Science* 57(3), 537-560.

Magnus, P.D. (2006). What's new about the New Induction? *Synthese* 148(2), 295-301.

Miller, D. (1994). *Critical Rationalism: A Restatement and Defence*. Chicago: Open Court.

Miller, D. (Ed.) (1983). *A Pocket Popper*. Oxford: Fontana Paperbacks.

Nagel, T. (1986). *The View from Nowhere*. New York: Oxford University Press.

Nisbett, R. & L. Ross. (1980). *Human Inference: Strategies and Shortcomings of Social Judgment*. Englewood Cliffs: Prentice-Hall.

Niiniluoto, I. (1987). *Truthlikeness*. Dordrecht: Reidel.

Oddie, G. (1986). *Likeness to Truth*. Dordrecht: Reidel.

Peirce, C.S. (1955). The Scientific Attitude and Fallibilism. In Justus Buchler (Ed.), *Philosophical Writings of Peirce* (pp.42-59). New York: Dover Publications.

Popper, K.R. (1989). (5th Ed. Revised.). *Conjectures and Refutations. The Growth of Scientific Knowledge.* London: Routledge.

Popper, K.R. (1983). Scientific Method, The Aim of Science, Truth and Approximation to Truth, Realism. In D. Miller (Ed.), *A Pocket Popper* (pp.133-142, 162-170, 181-198, 220-225). Oxford: Fontana Paperbacks.

Popper, K.R. (1981). The Rationality of Scientific Revolutions, In I. Hacking (Ed.), *Scientific Revolutions*, (pp. 80-106). Oxford: Oxford University Press.

Psillos, S. (1999). *Scientific Realism. How Science tracks Truth*. Boston: Routledge.

Psillos, S. (1997). Kitcher on reference. *International Studies in the Philosophy of Science*, 11(3), 259-272.

Putnam, H. (1981). *Reason, Truth, and History*. Cambridge: Cambridge University Press.

Putnam, H. (1975). *Mind, Language, and Reality*: *Philosophical Papers, Vol. 2.* Cambridge: Cambridge University Press.

Reed, B. (2002). How to think about fallibilism. *Philosophical Studies*, 107, 142-157.

Rescher, N. (1980). *Scepticism: A Critical Reappraisal*. Oxford: Blackwell.

Rysiew, P. (2011). "Epistemic Contextualism", *The Stanford Encyclopedia of Philosophy (Winter 2011 Edition)*, Edward N. Zalta (ed.), URL = <http://plato.stanford.edu/archives/win2011/entries/ contextualism-epistemology/>.

Rysiew, P. (2001). The Context-sensitivity of Knowledge Attributions. *Noûs*, 35(4), 477-514.

Schaffer, J. (2004). From Contextualism to Contrastivism. *Philosophical Studies*, 119(1-2), 73-103.

Schiffer, S. (1996). Contextualist Solutions to Skepticism *Proceedings of the Aristotelian Society*, 96, 317-333.

Shannon, C.E. (1948). A mathematical Theory of Communication. *Bell System Technical Journal* 27, 379-423, 625-656.

Stanford, K. (2009a). Underdetermination of Scientific Theory, *The Stanford Encyclopedia of Philosophy (Winter 2009b Edition)*, Edward N. Zalta (ed.), URL = <http://plato.stanford.edu/archives/ win2009b/entries/scientific-underdetermination/>.

Stanford, K. (2009b). Scientific Realism, Atomic Theory, and the Catch-All Hypothesis: Can We Test Fundamental Theories against All Serious Alternatives? *British Journal for the Philosophy of Science* 60, 253-269.

Stanford, K. (2006). *Exceeding our Grasp. Science, History, and the Problem of Unconceived Alternatives*. Oxford: Oxford University Press.

Stanford, K. (2003a). Pyrrhic Victories for Scientific Realism. *Journal of Philosophy* Vol.100(11), 553-572.

Stanford, K. (2003b). No Refuge for Realism: Selective Confirmation and the History of Science. *Philosophy of Science* 70, 913-925.

Stanford, K. (2000). An antirealist Explanation of the Success of Science. *Philosophy of Science* 67, 266-284.

Stanley, J. (2004). On the Linguistic Basis for Contextualism. *Philosophical Studies*, 119(1-2), 119-146.

Toulmin, S. (1972). *Human Understanding: The collective Use and Evolution of Concepts*. Princeton: Princeton University Press.

Van Fraassen, B.C. (1980). *The Scientific Image*. Oxford: Oxford University Press.

Vicedo, M. (2000). 'Experimentation in Early Genetics. The Implications of the Historical Character of Science for Scientific Realism'. In R. Creath & J. Maienschein (Eds.), *Biology and Epistemology* (pp. 215-243). Cambridge: Cambridge University Press.

Votsis, I. (2005). The Upward Path to Structural Realism. *Philosophy of Science* 72(5), 1361-1372.

Weiner, M. (2005). Must we Know What we Say?. *The Philosophical Review*, 114(2), 227-251.

Whittaker, E.T. (1951). (Revised edition). *History of the Theories of Aether and Electricity*. London: Thomas Nelson and Sons, Ltd.

Williams, B. (2002). *Truth and Truthfullness*. New Jersey: Princeton University Press.

Wilson, J.T. (1968). Static or Mobile Earth: The Current Scientific Revolution, *Proceedings of the American Philosophical Society* Vol.112(5), 309 – 320.