Foundations of Scientific Research in the Sport and Exercise Sciences

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Feedback
If you would like to provide feedback on this chapter, please email me directly (james.steele@solent.ac.uk), or use https://web.hypothes.is/. For the latter you can create a free account in about a minute. Then download the browser extension or bookmarklet, download this pdf locally but *open it in your browser*, activate the hypothes.is extension/bookmarklet, and then you can add feedback directly via annotations. Afterwards, email or share the pdf file and I will be able to see this feedback via the hypothes.is fingerprint on the file. See this video for more information https://web.hypothes.is/annotating-pdfs-tutorial/. Note, I plan to incorporate a full glossary prior to final publication of the textbook, but would appreciate feedback on what terms are best to include.

Contents

1.0 Introduction

This is a book about *research methods*. Specifically, a book about research methods in the *science*[a] of sport, exercise, and related areas. Naturally, a starting point then might be to consider the question's *"what is 'research'?", "what is 'science'?"*.

Now, many of you dear readers may already have some conception of what you think scientific research is. Mention of the words might conjure images in your mind of sitting in a library and perusing stacks of books and articles from its archives (or more likely nowadays, searching the internet and scrolling through page after page of content from digital archives). Or it may bring to mind an individual wearing a white coat in a lab tinkering with specialised equipment or strange liquids in test tubes. Maybe you think about someone embedded in an environment observing carefully the behaviour of the individuals within it and their interactions with one another. Perhaps you see

[a] Whilst there are of course other kinds of research, for example historical research, that could be conducted in sport and exercise and indeed have been (see Massengale[1]) we focus on scientific research here.

someone interviewing another person, asking questions, listening intently to their answers, and recording their thoughts. Some of you may see 'research' and 'science' as being synonymous with one another. Research being a systematic approach to problem solving, to producing knowledge, and isn't science exactly that? Perhaps, perhaps not.

Many have offered definitions for what they consider to be sport and exercise *science*[2,3]. Most of these however focus upon the question of what the disciplinary focus of the sport and exercise sciences is as opposed to the question of what the *science* part actually entails. There is debate as to whether we should consider the methods followed, and thus research conducted, in these substantive disciplines to be *science* at all[4–6].

This chapter is aimed at the introduction and clarification of important foundational concepts; or, at the very least, making you aware of the philosophical background and debates surrounding them. To forewarn you, there will not be a clear-cut answer waiting at the end of the chapter regarding what "scientific research" is. So, if it is this you seek than you are looking in the wrong place. Instead, this chapter will invite you on a journey inward where you consider and reflect on your position as a researcher. You may not realise it right now but much of what you will do as a researcher in the sciences is fundamentally influenced by the particulars of the philosophical assumptions that you bring along for the ride, knowingly or otherwise. It is through considering and reflecting on these assumptions that you will come to an answer as to what your research, your science, is. So, my sincerest apologies in advance dear reader… this first chapter is all actually about *philosophy*. My task is to make it clear why you should care about, and try to understand, this as the starting point for your research.

1.1 Why should you care about philosophy as a sport and exercise science student?

"A knowledge of the historic and philosophical background gives that kind of independence from prejudices of his generation from which most scientists are suffering. This independence created by philosophical insight is—in my opinion—the mark of distinction between a mere artisan or specialist and a real seeker after truth."

Albert Einstein, Letter to Robert Thornton, 1944

Despite the common modern perception of scientists that philosophy is entirely different from, and in some ways antagonistic to[b], science, the two share a long and intertwined history. Indeed, a key precursor to modern conceptions of science was in fact a branch of philosophy. Natural philosophy was the common term for the study of physics (i.e., nature), a broad term that included many of the physical sciences we have today (e.g., botany, zoology, anthropology, and chemistry as well as what we now call physics[c]). Here I want to briefly make the case that, whether you like it or not, philosophy forms a fundamental part of scientific research, that understanding and embracing it can have an important and productive impact upon your research, and ultimately why you, as a student of the sport and exercise sciences, should care about philosophy.

Parry[8], in discussing whether sport and exercise scientists should think philosophically about their science, offers two key arguments in the affirmative[d]. Firstly, and as mentioned above, philosophy is not simply a different subject from science, or even maths, history, and the rest. It is constitutive of them and with reference to them. Philosophy encompasses philosophy of science,

[b] For example, well known scientists such as Neil deGrasse Tyson and Richard Dawkins have been outspoken critics of the value of philosophy (for example, see the blog post by Massimo Picliucci[7]).
[c] Isaac Newton's book *Philosophiæ Naturalis Principia Mathematica* (1687) (English: *Mathematical Principles of Natural Philosophy*) reflects the use of the term *natural philosophy* in the 17th century.
[d] Actually, his arguments regard what a philosopher might have to offer in the sport and exercise sciences. But philosophers, like other methodologically inclined experts including statisticians, that take a substantive interest in these fields are few and far between unfortunately. So, I co-opt the arguments here to instead say why *you* should take an interest in philosophy and apply it to your work (though if you can work directly with philosophers then you certainly should).

philosophy of mathematics, philosophy of history etc. Each substantive area is only adequately understood when explored with at least some attention to philosophical considerations. Secondly, although the activities of philosophy are sometimes engaged in by scientists in their substantive work (e.g., of conceptual clarification, criticism, and the examination of assumptions, presuppositions[e], and justifications), this is often without explicit exposure to understanding these procedures. Whilst it is itself a researchable question as to whether education in philosophy might help scientists in doing their science, I can say I am sure it has helped me and I believe I am not alone in this regard (e.g., see Weinberg[10]; Meehl[11]; Laplane et al.[12]). Without an understanding of the tools of philosophy, scientists are trained to be little more than technicians without an understanding of why they are doing what they do. The philosopher of science Karl Popper perceived what he believed to be a worrying trend in this regard and one which seems to have continued to this day:

> *"In this context, one point should be mentioned, a point which I think may be connected with the present* [1968] *crisis of the universities. It is this. More and more technicians are needed, and as a consequence, more and more Ph.D students are trained only as technicians. Often they are trained only in measuring techniques. And they are not even told what more fundamental problems are to be solved by the measurements they are doing for their doctor's thesis."*

Popper, 1995[13]

In the following sections of this chapter I will outline some of the key philosophical concepts that make up the typical structure of the sciences and discuss their interrelationships (figure 1). Grix[14] refers to these as the '*building blocks*' that students need before they then begin to train and understand scientifically their substantive disciplinary traditions. Many research methods textbooks within the sport and exercise sciences focus primarily on the introduction of methodologies, specific methods, and the handling and analysis of data they generate whilst omitting explicit introduction to the more foundational concepts of *ontology* (what there is to know about) and *epistemology* (how do we know about it)[f], and the various philosophical traditions that are comprised of different ontological and epistemological positions. This *'methodology-led'* or *'methods-led'* approach to research training is unfortunate as, in my opinion, it resigns students to become primarily technicians[g]. Instead, *'question-led'* research from a firm foundation of the ontological and epistemological assumptions brought to the table seems a far more logical approach to this game we call science.

[e] A presupposition of an argument pertains to a propositional element (either the premise or conclusion) and is a necessary condition for the truth of the argument or for some component of it to have a referent. A assumption on the other hand pertains to the whole argument and is integral to the inferential structure of the argument (see Plumer[9])

[f] Although Fryer[15], in his *A short guide to ontology and epistemology*, notes once seeing a tweet along the lines of *"if you know what ontology and epistemology are without googling, then there's a 100% chance you're a douche"*. So maybe don't laud your newfound understanding of them as a result of the next section too readily over your peers.

[g] I should note that there is nothing inherently bad about being a 'just' a technician… in fact in today's fact paced modern world there are actually calls for a greater delineation of expertise and roles within big team science. The European Organization for Nuclear Research (CERN) is a great example of this, and other fields such as psychology have called for a move towards this[16]. In the meantime, and even for those whose aspirations lie more along the technical pathway, I do believe that at least some training in philosophy can be beneficial to enhance awareness of the larger scientific enterprise that we are engaged in.

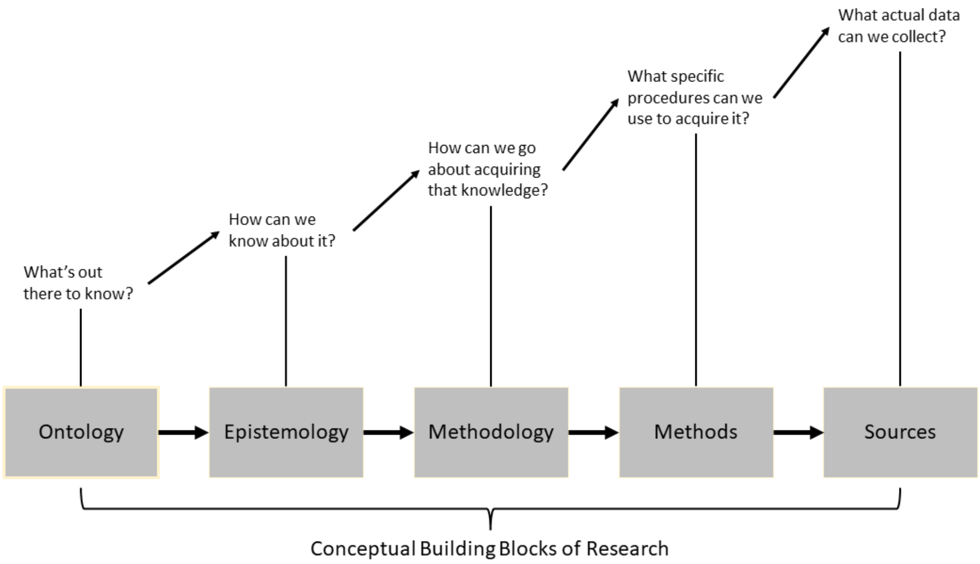

Figure 1. The conceptual building blocks of research and their interrelationship (adapted from Hay[17] and Grix[14])

Further, as Peter Caws[18] distinguished in his classic introductory text *The Philosophy of Science: A Systematic Account*, we can divide it into four main branches: ontology, the theory of being; epistemology, the theory of knowledge; *logic*, the theory of inference; and *axiology*, including ethics and aesthetics, the theory of values. Though explicit coverage of ontology and epistemology is often found wanting in most introductory research methods texts, both logic and axiology are perhaps even more neglected. So, we will also introduce them here and how they pertain to the research you might set out to conduct.

So dear reader, there are compelling reasons why philosophy should matter to you. Engaging with philosophy goes beyond the realm of being a mere technician skilled in designing studies, collecting and analysing data, and reporting on findings. You will of course learn all about these topics too throughout the chapters of this book. But learning about philosophy is about equipping yourself with more than just these practical abilities; it is about arming yourself with the rapier sharp and powerful tools that philosophers possess. Embracing philosophy has the potential to transform you into a true *scientist*.

Box 1. Reasons to care about philosophy in scientific research.

A) Philosophy provides historical context to modern science and its various branches and can thus help scientists to understand and appreciate the evolution of their respective fields.

B) By engaging with philosophy, students can move beyond being mere technicians who are only capable of designing studies and handling data and can instead become real seekers of knowledge with a deep understanding of the foundational concepts of their field.

C) Studying philosophy can help students improve their communication skills and become better at articulating complex scientific concepts and theories.

D) Philosophy can help students come up with more creative and innovative research ideas, including theories, models, study designs, analyses etc., as it encourages checking of assumptions, lateral thinking, and outside-of-the-box problem-solving strategies.

2.0 Ontologies and epistemologies and their role in science

"The practice of science depends on a set of metaphysical and epistemological commitments that are so commonplace that they rarely rise to the level of explicit consideration or discussion, at least among scientists."

Schwartz, 1990[19]

Ontology, followed by epistemology, are necessarily the starting points for all research. From these, and given the research question to be addressed or indeed even the questions that can be asked, one's methodological positions, methods, and interpretations of data logically flow. Understanding your own positions regarding these are therefore essential to determining the approaches that should be taken in the pursuit of your own research. This is also essential given the intersubjective and social nature of science as a broader undertaking. As mentioned, the tools of philosophy include conceptual clarification, criticism, and the examination of assumptions, presuppositions, and justifications. Scientific researchers often discuss and debate amongst one another regarding the research they conduct and theories they hold. But, without an understanding of the ontological and epistemological foundations of someone's work, the assumptions, or presumptions they begin from, we can find ourselves talking past one another. For instance, a researcher working from a position of behaviourism, grounded in the philosophy of logical positivism[h], may be interested in explaining physical activity behaviour. Any critique stating that their research does not consider the influence of unobservable psychological and social structures may be dismissed by them as irrelevant. To them these are not relevant concepts to consider based upon their ontological and epistemological position. Many scientists are unaware of the nature of the implicit ontological and epistemological positions that they adopt[i].

So, what are *ontology* and *epistemology*? These seem like big scary words but, despite several thousand years of philosophical debate and arguments for and against different assumptions regarding them, their definitions are relatively simple. Let's define them first, and then explore some of the varying positions regarding them and the philosophical traditions they refer to.

2.1 Ontology

In its simplest form ontology regards 'what there is to know about'; that is, what things are out there that we can attempt to obtain knowledge of. Within philosophy more broadly ontology is a main branch of what is called metaphysics which has many other branches such as cosmology which addresses very big picture questions such as the origin of the universe itself. More specifically though, ontology is about reality and how it is structured; what it is made up of, what it contains, how are these things structured, and how do they relate to one another? For the student of sport and exercise science, indeed any science, understanding ontology is about understanding what you think makes up the reality that you are trying to investigate.

It is important that you can understand, acknowledge, and defend the ontological position that you operate from. You need to be able to answer the question, whether you are explicitly asked it or not[j], *"what do I assume is the nature of the reality that I am trying to investigate?"*. For example, you might use terminology to refer to concepts such as 'force', 'strength', or 'self-efficacy' in the questions you ask and the research you conduct. Do you consider these to be actual 'things' that really exist? Do their definitions *"carve nature at its joints"* as the metaphor from the Greek Philosopher

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[h] See a more comprehensive explanation of this in the sections below.

[i] Yucel[20] presents an interesting exploration of scientists ontological and epistemological views elicited through semi-structured interviews.

[j] And often, at least in PhD viva examinations, you are explicitly asked this question and that of your epistemological commitments. Below I argue that you should think about using explicit positionality statements regarding these commitments for transparency.

Plato's *Phaedrus* suggests? Or are they merely convenient fictions, useful for a current purpose but not contingent on their 'really' being a corresponding 'truth' to them in reality?

In reflecting about your ontological position there is one thing to keep in mind; it is inherently assumptive. We cannot go out and empirically test them to have knowledge of whether they are 'true'. The Philosopher of Science Roy Bhaskar[k] calls this idea of reducing questions of ontology to those of epistemology the *epistemic fallacy*[l]. It is worth stating clearly here that it is absolutely fine to embrace the subjectivity of your ontological position. You may hold a particular intuition about it; a belief, or a tendency to believe, or a feeling that something seems to be the case. It is also perfectly acceptable to be unsure about it and to reflect upon it from time to time. It is also no problem to adopt different positions because of this reflection over time. But, for any given question we attempt to answer through research, we have to start somewhere or forgo the journey of moving from thinking about reality to trying to produce knowledge about it altogether. It is only after this question of *what we assume there is for us to know about* has been asked and answered can we move to the task of asking what, and how, we can *know* about this reality.

2.2 Epistemology

We must consider what we can indeed know before we consider how we come to know things, how we produce knowledge. Epistemology follows logically from ontology, and this is exactly what epistemology is; *"what we can understand, and how we can understand it, regarding the reality that we assume we are confronted with?"*. Epistemology then refers to theories of knowledge; how it is justified[m]. For the student of sport and exercise science, and again any science, understanding epistemology is about understanding how you can come to obtain knowledge about the reality that you are trying to investigate.

The nature of knowledge is dependent on firstly the ontology we assume, and secondly on the ways in which we assume we can come to justifiably obtain it. Some believe that scientific knowledge, the theories that it produces, is aimed at representing and attempting to explain truthfully the nature of the reality that we wish to understand; that scientific research seeks out the truth of matters. Others though see scientific knowledge as purely instrumental; that is to say more or less useful for a particular purpose but not more or less true. Some deny that there even is such a thing as truth that we might aim to know.

Similarly, to ontology, it should be clear that the epistemological stance we adopt too will impact the nature of the research we conduct and thus the views on phenomena that we hold. Indeed, it can impact the very aim of our research.

2.3 Frameworks for understanding ontological and epistemological positions

As you might suspect there are many nuanced positions that can be adopted with regards to both ontology and epistemology, and thus in combination they can give rise to an assortment of philosophical traditions. You may have come across some of the names of many traditions already. Objectivism, subjectivism, interpretivism, positivism, phenomenology, transcendental realism, critical theory, critical rationalism, post-positivism, post-modernism, hermeneutics… every philosopher seems to want to come up with their own brand for the framework they offer. Such a range of terminology can leave students confused and feel that philosophy is overly complex, perhaps even complex for complexities sake. But, to let you in on a little secret… many of these traditions have key elements in common that allow us, much to the offence of the philosophers themselves I would

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[k] More on him and his ontological and epistemological positions below.

[l] Bhaskar[21] however offered what he called the 'transcendental argument' for a realist ontology which held the logical form known as 'Affirming the Consequent'. Essentially: If the world has certain XYZ ontological properties then scientific experimentation is possible; scientific experiment is possible; therefore, the world has XYZ ontological properties. Later we will touch on valid and invalid forms of logical argument. Come back to this footnote afterwards and see if you can spot the flaw in this argument.

[m] Contrastingly, methodology refers to theories regarding how research should proceed and methods the specific procedures undertaken in the process of producing justifiable knowledge.

imagine[n], to group them simply across a two-by-two contingency table. So, lets simplify things and boil down ontology and epistemology each to two basic positions[o].

Regarding ontology we can distil it to the two opposing positions of *realism* and *anti-realism.* These positions are relatively self-explanatory and pertain to assumptions regarding whether they think there are objective answers to the basic question of ontology "*what exists?"*. A realist assumes there is an answer to this and, whilst not verifiably so as noted above, they assume that there is in fact a real universe filled with objectively definable things that exists out there independent of their own subjective experience. The realist believes that there are indeed "joints" at which we can carve nature into the objectively true *things* that it is made up of. Contrastingly, the *anti-realist* denies an answer to this question or at the very least denies that if there is a reality independent of our knowledge of it then it cannot exert influence on our knowledge claims which are purely about our subjective experience. In this sense the anti-realists think that no one attempt to carve up reality is truer than any other. Of course, as noted there are myriad nuances to these positions[p] which we will touch on below.

For epistemology, whilst again there are nuanced positions existing between these poles, we can broadly categorise it into *objectivism* and *subjectivism.* For the objectivist there is no assumed barrier to the production of knowledge; it is simply the case of making observations of reality and from this truthful knowledge about it can be attained. The subjectivist is more sceptical instead thinking that our observations, and thus knowledge, are influenced by a variety of things and therefore it does not necessarily follow that truth emerges in some neutral and objective manner.

So, as mentioned and given we have two positions for ontology (realism and anti-realism) and epistemology (objectivism and subjectivism), we can therefore create four categories in a two-by-two table: realism/objectivism, realism/subjectivism, anti-realism/objectivism, and anti-realism/subjectivism. Let's explore each of these categories[q] in turn and the common philosophical traditions they describe. I will do my utmost to avoid being prescriptive here about which positions I think you *should* adopt[r]. Instead, I want you to consider them all and think for yourself about which to adopt. Some argue for a form of 'practicalism'; that questions of ontology and epistemology don't matter so much for practicing researchers. That you can adopt whichever position you find convenient for a given purpose. This maybe fine at the methods step of research to an extent, but regarding ontology and epistemology this makes little sense given their logical precedence. You should consider ahead of time your positionality regarding them and try to be coherent in your application.

2.4 Philosophical traditions in science

Broadly speaking, and though as mentioned there are a variety of flavours of philosophical tradition that subtly differ from one another, we can group them into three broad positions[s] (table 2): Positivism, Constructivism, and Critical Realism. You'll notice that in table 1 the ontological and epistemological positions noted are aligned to each philosophical tradition. In addition, there is a further column pertaining each traditions analysis of causes. We'll get to this as we introduce and summarise each of the traditions but in essence it considers whether each position considers causes to be part of their ontology or not.

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[n] As I said, there are nuances between the various positions but often there are considerably similarities, and the differences are more often more of 'degree' than of 'kind'. They are perhaps more or less extreme in certain matters along a spectrum of positions, probably more reflecting the sensibilities of the philosopher.

[o] Fryer[15] follows this approach in his short guide.

[p] See this video from Vsauce "Do Chairs Exist?" for a great overview of various perspectives on ontology.

[q] I am however going to exclude on – anti-realism/objectivism – similarly to Fryer (2020). As he notes, it is contradictory in the first place to assume no independent objective reality but think we can produce objective knowledge.

[r] Though later I will be clear about what mine are for the purpose of transparency. That way you can appraise the extent to which you think I may have been balanced in my portrayals of them.

[s] This is also the categorisation that both Fryer[15] and Yucel[20] adopt. It's worth noting though that even this language and grouping might upset some philosophers and writers on these topics. For example, Levers[22] refers to constructivism as taking a critical realist ontological position alongside epistemological subjectivism. I would encourage you dear reader to try to see past the hodgepodge of confusing and often contradictory labels and try to grasp the key ideas.

Inevitably, as already mentioned, there is far greater nuance to the views of the various players in these philosophical traditions that I can provide here without risking boring you with dialectical analysis. Westbrook[23] offers a thought regarding the varied thinkers within the pragmatist tradition that could be easily applied across most if not all philosophical traditions that end up with broad labels, that they are *"…less as a well-defined, tightly knit school of thought than as a loose, contentious family of thinkers who have always squabbled, and have sometimes been moved to disown one another."* So instead, I offer a little background and summary of each which might prompt you to want to explore further in the future.

Table 1. Ontological and epistemological commitments and analysis of causes in different philosophical traditions

Tradition	Ontological Commitment	Epistemological Commitment	Analysis of Causes
Positivism	Realism	Objectivism	Patterns/constant conjunction of events
Constructivism	Anti-realism	Subjectivism	Mental models
Critical Realism	Realism	Subjectivism	Mechanisms/tendencies

2.4.1 Positivism

The term *positivism* was introduced by Auguste Comte who, inspired by Scottish philosopher David Hume's empiricism, skepticism, and naturalism, became one of the first philosophers of science in the modern sense and wanted to capture the qualities he valued *positively* in his philosophy. Comte attempted to explain the development of human knowledge through his "Law of Three Stages" and is also hailed as the founder of the field of Sociology with his introduction of *Social Physics* applying the methods of the natural sciences to social phenomena. He held that in the procession towards scientific knowledge there was the need to rid it of theological and metaphysical ideas. In the early twentieth century a group of influential philosophers, logicians, mathematicians, and scientists collectively known as the Vienna Circle [t] built upon Hume and Comte's philosophy uniting it with new developments in logic. They placed a strong emphasis upon the importance of logical and linguistic analysis of the justification of scientific claims from empirical observation taking on the name of the logical empiricists, though the term logical positivism is often seen nowadays[u].

As noted, positivists take the ontological stance that the world consists of real things and that epistemologically we can gain objective knowledge about this reality. Specifically, positivists typically hold that there are general facts and universal laws that describe reality and we can come to know them through a process of verification via empirical observation. This realism holds that facts and laws are universal and independent of us as subjective observers. The objective epistemology of the positivists, and more specifically the logical empiricists/positivists, was primarily one of *verification*. Verificationism, or the principle of verification, was aimed at removing metaphysical statements from their philosophy by focusing on what conditions led to statements that contained meaning. For them a statement was meaningful, which is to say it pertains to something true, only if it is true analytically or is empirically verifiable via observation through our senses or methods to enhance them such as the technical tools of different sciences (e.g., the telescope in astronomy). Statements that are true analytically are those which are true logically such as tautologies i.e., true by definition; for example, the statement "all bachelors are unmarried men" is definitionally true and equivalent to saying, "all unmarried men are unmarried men". Alternatively, the statement must be empirically verifiable. For

[t] Because they were based in Vienna and regularly met in coffee shops and eventually the mathematics department of the University of Vienna (see Edmonds[24] for a fascinating history of the Vienna Circle).

[u] Although, few of the founders of many of these ideas in philosophy adorned the label of logical positivism, one was A. J. Ayer[25] who espoused the *verification principle* that was broadly accepted within the wider movement. The first use of the term 'logical positivism' though came in Blumberg and Feigl[26] on introducing the new philosophical movement in Europe to American audiences.

example, the statement "the sun will rise tomorrow" has meaning because we can determine the truth or falsity of the statement by waiting until tomorrow and observing whether indeed the sun rises. This is often called the analytic-synthetic dichotomy following the terminology introduced by philosopher Immanuel Kant.

Epistemologically, under the tradition of positivism, scientific theories are seen as objective descriptions of the universal laws that make up reality. Hacking[27] provides a summary of the key tenets of positivism. Our knowledge, the descriptions of universal laws, can be verified, or indeed falsified, through observations which refer to the constant conjunction of events. There are no causes per se which exist in nature[v], only the constant conjunction of events (i.e., one event is invariably followed by another) which we can observe and describe via universal laws. As such, the positivist downplays the role of explanation and does not consider there to be deeper answers to questions such as 'why?' or 'how?' beyond the description of the regularly occurring phenomena. Lastly, and similarly to causes, positivists do not permit the inference from observations to other underlying unobservable theoretical entities that might 'explain' observations[w]. Constructs are defined only by their specific operational forms i.e., each and every kind of operation we perform to observe something defines the construct that we observe [29]. This is not to say that they velieve these things to not exist, but that they are not legitimate objects of science. The real things that science can produce knowledge of to them are those which are observable through such operations and, via induction[x] we can come to know the structure of nature's laws.

2.4.2 Constructivism

The view of constructivism is that both reality and scientific knowledge are a human and social construction. Constructivism as a term has been used in many different ways at different points in time across philosophy, and also sociology and education, though in general was a reaction against the dominant positivism of the early to mid-20th century. For example, the Swiss child psychologist Jean Piaget developed the 'constructivist' theory of learning, contrasted with the similar term yet different theory of 'constructionism' by Seymour Papert. We will focus on constructivist thinking in the philosophical sense here and consider its ontological and epistemological commitments.

I have perhaps been somewhat unfair up till this point in saying that constructivists are anti-realist in their ontology. Some constructivists do explicitly adopt this ontological position. For example, Ernst von Glasserfield was a key proponent of radical constructivism and made clear *"It is the primary and most essential aspect of radical constructivism that it deliberately and consequentially avoids saying anything about ontology, let alone making any ontological commitment"*[30]. But most constructivists would be more likely to adopt a *relativist* position regarding ontology which asserts that reality is a finite subjective experience and not distinguishable from this experience. In this way of thinking about ontology, reality *is* experience and vice versa. Thus, the position goes beyond the possibility that two observers might merely subjectively experience an objective external world differently. Instead, it holds that the worlds they experience, whilst different, are in fact both real. Constructivists do not necessarily deny the existence of a world external to us, but they do not equate it with reality instead seeing it as just one thing which can influence our individual realities. As such, there are as many realities as there are subjective observers to experience them and the purpose of epistemology from this ontological position is to understand the subjective experience of reality and its multiple 'truths'.

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[v] Though even within the logical positivist tradition there was and is variety in how causality is typically conceived (for example, see McGuinness[28]).

[w] For example, and to return to our behaviourist researcher in section 1.2, it would not be permissible to infer from overtly observed physical activity behaviour to unobservable mental representations of motivation. Instead, the initiation of physical activity behaviour is defined as motivation itself. Even the operation of asking a person and having them self-report their "motivation" would be considered merely as a behavioural event and not necessarily reflective of some unobservable mental experience. So goes the old behaviourist joke… two behaviourists meet each other at a conference, and one says to the other "You're doing well, but how am I?".

[x] We will discuss different kinds of inference including induction in the sections below.

The subjective epistemology of constructivism that follows from this relativist ontology is then necessarily one of relativism. If reality is always constructed from the relative position of a given subjective observer, then knowledge of it is too and is always filtered through the unique lenses of that individual. Different observers may have different realities and interpretations of these thus having different subjective knowledge. Examples often given are bistable (i.e., reversing) illusions such as the Rubin Vase (figure 2).

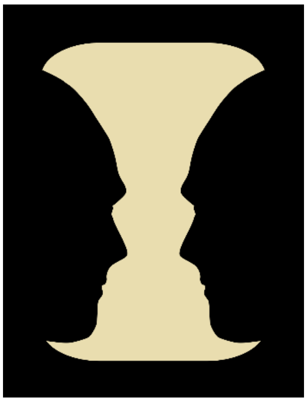

Figure 2. A Rubin Vase – this bistable illusion can be seen as either a light vase upon a dark background, or two dark silhouettes of faces looking at one another with a light background.

Within such images there is no 'true' perception of what the image is really of. Relativism then to an extent sees knowledge as fallible, a statement claiming truth might be wrong; though, given its ontological position it is difficult to see exactly how this is determined and some claim that instead there are many 'truths'. Interestingly, although the positivists downplayed explanation, within constructivism a similar inductive approach is employed yet aimed explicitly at explanation. Working 'upwards' from details of particular cases to adduce theories capturing the relevant patterns and relationships within them. However, there is not claim to 'truth' regarding such explanations. Theories are typically seen by constructivists as being pragmatic, of instrumental value, as they appear to solve problems and allow us to predict things[y]. The historian of science[z] Thomas Kuhn[33] was influential in convincing many scientists of relativism and that scientific knowledge was contained within, and determined by, the conventions of a given theory or paradigm which was deemed incommensurable with another[aa]. As such, the knowledge within subjectivist epistemology focuses upon explaining discourses, meanings, and experiences of the knowing subjects – us.

2.4.3 Critical Realism

Critical realism broadly speaking and the many philosophical positions that adopt its main views was, similarly to constructivism, a reaction to the predominant positivist thought in the early to mid-20th century. Two key philosophers of science who were, largely independently[bb], influential in addressing what was thought to be the naïve realism[cc] of positivism were Karl Popper[35] and Roy Bhaskar[21].

Ontologically, as the name suggests, those within the broad tradition of critical realism do hold that there is a reality independent of us as observers of it and that this objective reality is the target of our research and science. Popper's ontology was structured as what he referred to as World

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[y] There is affinity here with the tradition of pragmatism (see Hickman et al.[31]). Irribara[32] in presenting a pragmatic perspective on measurement nicely summarises the central ideas of pragmatism: the primacy of practice, fallibilism, anti-skepticism, the historical and social nature of knowledge, the anti-representational stance, and the conceptualization of our theories as tools.

[z] Some refer to Kuhn as a philosopher of science, yet he saw himself as more a historian documenting how science progressed.

[aa] Conventionalism of one form or another has been at the heart of many controversies in science including those regarding the nature of time itself by Albert Einstein and Henri Bergson[34]

[bb] The views of Karl Popper and Roy Bhaskar were in many ways very similar in their core positions regarding ontology and epistemology, though some subtle differences in how they arrived at them and nuances between their overarching philosophies. Bhaskar's writing came later though and mostly ignored Popper's prior work.

[cc] The notion that we could obtain objective knowledge of reality as it is merely through observation.

1, 2, and 3, and Bhaskar structured his into what he referred to as the intransitive objects of knowledge, and the transitive objects of knowledge. The World 1 and 2 of Popper's ontology referred to the realm of structures, states, and processes that the natural sciences look to study, and the realm of mental states and processes respectively. But Popper only delineated these in a chronological sense; before there were conscious beings capable of experiencing mental states there were still all sorts of other objective things. In modern science the two are part of the broader ontology of 'things we research' and the interaction of them encompasses both the natural and social sciences and rejects old notions of Cartesian dualism[dd]. For Bhaskar, his intransitive objects of knowledge offer essentially the same idea and encompassed what he called the *real* (i.e., the domain of causal powers and mechanisms) and the *actual* (i.e., the domain of actual phenomena and events caused by the underlying mechanisms)[ee]. Both philosophers agreed that science begins with a realist ontological position; that the knowledge we generate is *of* the things that make up reality.

Popper's World 3, and Bhaskar's transitive objects of knowledge are where our *empirical* experiences and observations of the other worlds as well as the products of their epistemologies are situated. It is home to the scientific theories we offer as explanations of reality as ideas themselves. Unlike the positivists though who sought certain knowledge through verification, both Popper and Bhaskar embraced the inherent uncertainty and fallibility of the knowledge we produce of reality. We will touch more on the specific modes of inference used in their epistemology in a section below, but here it is sufficient to say that both were comfortable with theories that postulated the existence of unobservable entities that might explain the phenomena we observe, including the proposed underlying causal powers and mechanisms that tend to produce actual phenomena. Bhaskar even specified that whilst, as it appears to us, reality is comprised of our empirical experiences of the events and structures occurring out there in reality, it is the underlying causal mechanisms of these that are the real targets of our knowledge and theories. The key for both though was that our knowledge was not free from our subjective discourses, meanings, experiences, and values. Thus, all our knowledge is fallible and not the product of purely detached observation. The aim was to acknowledge this and strive for theories that got as close to the truth as we could, to have high verisimilitude or truth-likeness, and to always hold them as tentative explanations of reality that will one day be proven wrong[ff].

2.4.4 Don't overthink the labels but do think about your position.

As I mentioned in the preceding section, there are almost as many named philosophical traditions as there are practicing philosophers. So, don't get bogged down in trying to determine how best to label yourself in that regard. Instead, try to just think carefully through the different positions you take regarding your ontological and epistemological assumptions.

[dd] René Descartes (1596 – 1650) was a French philosopher, scientist, and mathematician who famously defended the idea of substance dualism as an ontological position; that is, reality is comprised of two separate kinds of things – mental and physical.

[ee] Note that Bhaskar also saw these as being stratified across levels of explanation. For example, different levels of reality might contain different causal mechanisms for the phenomena and events that occur e.g., physical, chemical, biological, psychological, psychosocial, behavioural, social, cultural. Mechanisms, phenomena, and events at a lower level can create the conditions for mechanisms, phenomena, and events to 'emerge' at higher levels, and these are not over-determined or merely epiphenomenal (i.e., they are not explained by just describing the lower level elements but they are genuinely explanatory themselves and causally efficacious). See also the idea of 'real patterns' as discussed by the philosopher Daniel Dennett[36] or the tangled hierarchy of the 'strange loop' that Douglas Hofstadter presents[37,38].

[ff] Paul Meehl wrote a lovely poem embracing this titled *Verisimilitude*:

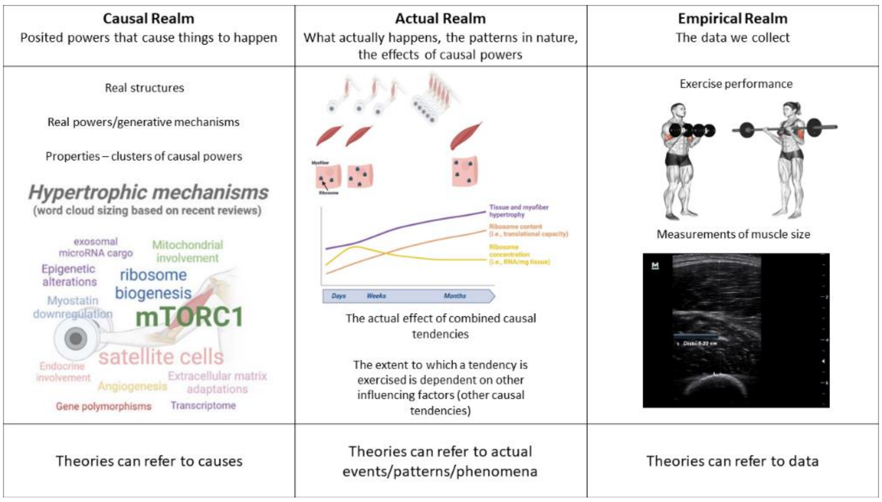
It makes a fellow cheery
To be cooking up a theory;
And it needn't make him blue
That it's not exactly true
If at least it's getting neary.

Exercise: Where do you position yourself ontologically and epistemologically?

As a task now, reflect on what we've covered to this point. The different descriptions of the philosophical traditions and how they relate to different ontological and epistemological positions. Below you will find a figure with an example of a research topic and our current scientific understanding of it: skeletal muscle hypertrophic adaptation to exercise (from Roberts et al.[39]). You'll also see three descriptions of different *worldviews*. Yucel[20] used these descriptions and similar diagrams to the one below to encourage scientists to reflect on their ontological and epistemological positions.

Read the worldviews and think about the example below. Which worldview best fits your positions? How does your position relate to the diagram below? Think about whether you consider scientific research to "discover or create", what you think about the nature of "uncertainty" and "truth" in science, the role that science plays in "society". Discuss your views with colleagues and see if you can discern where one another's positions lie with respect to ontology and epistemology.

- Worldview 1:
  - Theories are constructed from data. The patterns they purport to describe are purely constructed in the minds of scientists. We cannot know if theories map onto real patterns in nature. If theories make reliable predictions, they are accepted. There is no place for "truth" in science.
- Worldview 2:
  - Theories are constructed from data to describe real patterns in nature. We cannot directly observe these patterns, but we can infer them from the data we collect and analyse. Science can give us no knowledge of causal powers because we cannot gather empirical evidence about them. Causal powers are part of the realm of metaphysics (i.e. outside of the physical world) and thus are outside the realm of science.
- Worldview 3:
  - Theories are constructed from data to describe real patterns in nature. We cannot directly observe these patterns, but we can infer them from the data we collect and analyse. We can also infer from these patterns the causal powers that give rise to them, even though these causal powers are not entities in themselves, and we can have no direct empirical evidence of them.



3.0 The Axiology of Science - what values do we hold as scientists?

To this point we have focused only on a limited portion of the broader topic that is Philosophy of Science. Hopefully it is clear that the topics covered should indeed be of interest to you and improve your ability to do your research; thinking about what there is to know and how you might be able to create knowledge of it. But you might be thinking, why should I care about this topic of *axiology,* the theory of values? Why should I care about values? Well, Alvin Weinberg I think put it quite clearly when he wrote:

> *"…whether it is conducted at the level of the individual scientist who decides to do this rather than that, or at the level of the research director who sets a whole laboratory on this course or that, or at the level of the Bureau of the Budget, which directs a whole nation's science policy one way or another – in every instance* [science] *involves questions of value. Is it more important, or more valuable, or somehow better, to do this rather than that, to support high energy physics rather than nuclear physics, or oceanography rather than space science?*
>
> Weinberg, 1970[10]

Whilst it may not be obvious, axiological issues are implicit in the practice of science and to an extent can influence even the ontological and epistemological positions we take and how we apply them. Whilst the findings of research are interpreted in light of our positions regarding ontology and epistemology, we sometimes face in science the choice between two or more seemingly valid theories[gg] that equivalently explain the empirical evidence and yet are logically incompatible with one another[hh]. How do we choose in this situation? We appeal to *values* including ethics and aesthetics. Some argue it is a matter of *taste*. Einstein favoured *beauty* in scientific theories. Popper strove for *simplicity*. The biologist Peter Medawar valued the explanatory or clarifying power and originality of a theory. Values help bridge the gap in theory choice which is itself a complex form of value judgement. Some of those values are *epistemic* and pertain to our epistemological position[ii]. But some are broader than this with practical implications.

Science and research aim to tell us what *is,* whereas values are aimed at what *should or ought to be;* but we cannot derive one from the other[jj]*.* This means that science cannot ultimately tell us what we should do, even in the case of *doing science* itself, although it can inform our reflection for doing so. Some might argue that conversely, we should not let our values illegitimately influence our scientific practices. However, as we have seen, science cannot stay wholly value free. Normative ethical values such as regard for human and animal welfare influence research agendas and scientific practices including the methods we employ[kk]. Other nonepistemic values might also influence our epistemic practice. For example, when the consequence of making an error is high, the standard of evidence to draw conclusions is generally set higher[ll].

We too hold our own sets of values, perhaps influenced by our backgrounds and experiences, that may bias our actions as individual scientists. But this is where transparency and embracing our positionality in not only ontology and epistemology, but also our personal and cultural values, can help to improve our science. In fact, from a collective point of view, a diversity of positions in scientific

[gg] To give an extreme example the *ABC of Behaviour Change Theories*[40] purports to describe *"… 83 theories of behaviour change, identified by an expert panel of psychologists, sociologists, anthropologists and economists as relevant to designing interventions"*.

[hh] Referred to as the Duhem-Quine Thesis (after Pierre Duhem [1861-1916] and W.V.O. Quine [1908-2000]), contrastive underdetermination, or the underdetermination of theory by evidence.

[ii] For example, we might favour the role that facts and objectivity play in our appraisal of theories [41].

[jj] The Scottish Philosopher David Hume [1711-1776] first articulated this is-ought problem, sometimes referred to as *Hume's Law* or *Hume's Guillotine.* It is the thesis that an ethical or value judgement cannot be inferred based on purely descriptive factual statements.

[kk] Note, such normative ethical values often come from the scientific communities themselves as a result of discussion and debate quite independently of the formal institutional review boards or ethics committee process imposed to regulate scientists activities (see Schneider[42]).

[ll] This touches upon the concept of errors in statistical inference which are explained more fully in the chapter on statistics [insert chapter link].

communities can be viewed as a worthwhile value in and of itself. This so called *intersubjectivity,* or *collective objectivity* as it sometimes referred to, ensures transparent, critical discussions between individuals to enable a better identification of errors, or situations in which personal preferences or interests might override evidence[43,44].

Many views on what should constitute values in science have been shared over the years. Robert Merton's[45] sociological norms and counter-norms of science are a famous example (table 2).

Table 2. Mertonian Norms and Counternorms of Science

Norms	Counternorms
Communality Common ownership of scientific goods including findings, materials, data etc. Openness and transparency	*Secrecy* Scientists do not share their scientific goods. Closed and opaque.
Universalism Scientific validity is evaluated on its own merit independently of the sociopolitical status/personal attributes of its participants	*Particularism* Scientific validity is assessed based on the reputation and status of individuals or research groups
Disinterestedness Motivated by knowledge and discovery to contribute to a common scientific enterprise	*Self-interestedness* Motivated by individual benefits where science is treated as a competition amongst scientists
Organised skepticism Claims in science, even one's own work, are exposed to critical appraisal by the community before being accepted into the canon	*Organised dogmatism* Scientists invest their career in promoting their own claims, findings, theories, and innovations without self or community critique

A more recent set of *intellectual virtues* in science and scholarship where presented by Scwartz[46] who argues that we should try to internalise our values, pursue them for their own sake, and to practice acting on them regularly. The virtues he notes are:

- Love of truth[mm]
    - *"Scientists, scholars, and students need to love the truth to be good at what they do. They need to love the truth because discovering it is the point of their efforts, and because knowing the truth matters."*
- Fair-mindedness
    - *"Fair-mindedness enables us to face the limits of what we know; it encourages us to own up to mistakes. And it enables us to acknowledge uncongenial truths about the world."*
- Perseverance
    - *"Scientists, scholars, and students need the intellectual virtue of perseverance, since little that is worth knowing or doing comes easily."*
- Courage
    - *"Scientists, scholars, and students need intellectual courage, too. They need it to stand up for what they believe is true, sometimes in the face of mass disagreement from others, including people in authority like their professors or journal editors."*
- Perspective taking and empathy

[mm] Or "truths" depending on ones ontological and epistemological position.

  - *"Scientists, scholars and students need to be able to take the perspective of others, and empathize. This is especially true in an age in which almost all substantial work is collaborative."*
- Wisdom
  - *"Finally, scholars, scientists and students need the virtue that Aristotle called practical wisdom. Any of the intellectual virtues I have mentioned can be carried to an extreme. Wisdom is what enables us to find the balance…"*

Again, I do not want to seem prescriptive in my presentation of values in science and research. But, whether you agree with his values or not, Schwartz[46] point that we should cultivate our virtues through active practice is one we should be able to agree upon. I would add further that we should be actively reflexive around our values similarly to our other positions.

3.1 Embracing positionality in all research through reflexivity and reflection

The term *positionality* in research is used to refer to the position that you adopt in relation to the task of engaging in research. It is your worldview or 'where you are coming from'. It concerns the ontological and epistemological, and indeed other (e.g., values, personal characteristics, social position, experiences, and beliefs), assumptions discussed above and where you situate yourself in these regards.

Traditionally positionality is often somewhat hidden. Rarely do you find researchers explicitly stating their ontology and epistemology when you read their work. An exception to this might be in *qualitative* research where it is more common to state positionality in ontology and epistemology, though perhaps more common to state it in regard to other social and personal factors that could have influenced the research[47,48]. But there have been more recent calls to state positionality more clearly even in *quantitative* research[49,50].

Reflexivity is important to aid in understanding your positionality as a researcher. It refers to the conscious active acknowledgement and appraisal of your beliefs, biases, and assumptions both before, during, and after the research process. *Reflection* is like reflexivity, and encompasses it, but takes the purely retrospective view of these things considering what might have been overlooked during the research process. If positionality refers to what we know and believe, then reflexivity is about what we actively do with this knowledge.

A good positionality statement[nn] in its most basic form acknowledges openly the researchers ontological and epistemological positions regarding the research being conducted. But, where appropriate, it also reflexively considers values, personal characteristics, social position, experiences, and beliefs as they pertain specifically to the research at hand[oo].

[nn] Whilst positionality statements are argued to be in the spirit of openness and transparency and will aid researchers to better interpret others work, some have been critical of calls for statements to be included as standard in scientific research [51]. In particular this pertains to the inclusion of the latter set of positions (e.g., values, personal characteristics, social position, experiences, and beliefs) where Savolainen et al.[51] argue that statements in this regard do not serve their purpose, being necessarily influenced by positionality themselves; by focusing on positionality they miss the true source of bias in research (i.e., a failure to adhere to a collective scientific ethos); and lastly, that they are potentially harmful as they might undermine the norms and practices in place that safeguard the integrity of scientific research.

[oo] See Jacobson and Mustafa[52] for a framework on transparent reporting of these positional characteristics.

Exercise: Writing a Positionality Statement

Purpose:

The goal of this exercise is to articulate your positionality—your personal, social, and philosophical context that informs your understanding of the world, what is real and how you can come to know about it (ontology and epistemology)—and how this might influence your research approach and interpretation of results.

Instructions:

1. Identify your Positionality:

Begin by outlining your key personal and social identities and experiences that might be relevant to the research topic you are pursuing. This could include aspects such as your age, race, gender, sexuality, socio-economic status, nationality, education level, and so on. You might find some aspects more relevant than others to your research but try to be comprehensive at this stage.

2. Outline your Ontological and Epistemological Beliefs:

Next, identify and articulate your ontological position (your beliefs about the nature of reality and being) and your epistemological position (your beliefs about the nature of knowledge and how it can be acquired). For example, do you believe there is a single knowable reality or, multiple subjectively constructed realities? Do you believe knowledge is objective and can be discovered, or is it subjective, fallible, and constructed by you as the researcher?

3. Reflect on how your Positionality Influences your Research:

Reflect on how your personal and social identities, as well as your ontological and epistemological beliefs, might shape your approach to research and the interpretation of findings. Do you lean towards quantitative or qualitative methodologies (more on these in chapter [insert chapter link] – so you may want to return and engage in more reflexivity then)? How might your background and beliefs affect the research questions you pose, the theories you draw upon, the data you collect, or the conclusions you reach?

4. Write your Positionality Statement:

Using your reflections from the previous steps, write a positionality statement of approximately 250-500 words. This statement should clearly articulate who you are, your worldview (ontological and epistemological positions), and how these factors might influence your research.

5. Peer Feedback:

Exchange your positionality statement with a partner. Each partner should read the other's statement and provide constructive feedback. Does the statement clearly articulate the author's positionality and its potential impact on their research? Are there aspects of positionality that are missing or could be further elaborated?

Remember that a positionality statement is not a fixed or definitive document. It is a living reflection of your worldview and should evolve as you progress through your research and continue to learn and grow.

Example

Here is an example of a positionality statement written by myself:

Ontologically, I align myself with realism, the belief that an independent reality exists, separate from our conceptions and interpretations. Within that independent reality I include the unobservable contents of other subjective knowers minds; that is to say I don't merely assume that there is my *mind and the external objective world, but that the subjective experiences of others are indeed part of the independent reality that exists. I also assume the reality of underlying causal powers and mechanisms that give rise to the phenomena we observe in addition to the reality of postulated theoretical entities. This includes the notion of emergence, that concepts at different levels of explanation can be real and causally efficacious. I recognise that while this reality is independent, our access to it is invariably mediated by our perceptual and conceptual perspectives and the social influences that frame our understanding. This aligns with my adoption of the critical realist perspective, which marries the idea of an in principle knowable reality with the recognition of the limits of our knowing in practice.*

Epistemologically, I hold a subjective fallibilist position, acknowledging that our grasp on knowledge is tentative, liable to revision, and shaped by individual perspectives. I believe our understanding of reality is fallible, and while we may strive for objectivity, our interpretations are invariably influenced by our subjective perspectives. This leads me to a continuous quest to critique and improve upon our current understanding of reality, informed by the belief that we can never truly attain a complete or definitive account. Whilst I accept that in the context of discovery there is a difficult to pin down creativity to scientific theorising, I subscribe to the falsificationist position in the context of justification that we can never prove our theories are true descriptions of reality as it is, but we can disprove them. As such, I am open to methodological plurality in what constitutes the methods we use in science dependent on the epistemological context.

I recognise the importance of open critique, debate, and the pursuit of objective truth within the constraints of our individual and collective subjectivities. I strive to challenge assumptions, both my own and those embedded within the academic fields I am a member of, as part of a continuous process of reflexivity in knowledge generation and refinement. By and large I hold and try to cultivate those virtues listed by Schwartz[46]: Love of truth, fair-mindedness, perseverance, courage, perspective taking and empathy, and wisdom.

My position as a white, middle-class, heterosexual, cis-gendered male of 35 years, coupled with my geographical location in the United Kingdom, English as my first language, and my physical able-bodiedness, inevitably creates a unique lens through which I perceive the world and conduct my work. My personal circumstances and role as an academic originating in sport and exercise sciences puts me in a unique position, and I am acutely aware of the opportunities it has likely influenced. It has afforded me access to and inclusion within various communities and groups and inevitably influenced the kinds of research I am able to conduct, and likely the kinds of research questions I even think to ask or want to ask.

In essence, my positionality including my ontological and epistemological beliefs, though complex and nuanced, guide my research. They influence what questions I consider asking, how I pose those questions, interpret findings, and contribute to the broader knowledge base in my field.

4.0 Logic, reasoning, and inference as a key part of science

Logic, which might be defined as the theory of reasoning or inference, plays a considerable role in scientific research. It is a non-empirical field much like mathematics or the other areas of philosophy already discussed, and yet similarly to these has major implications in our ability to draw conclusions regarding our empirical world. To say logic is the theory of reasoning is not to say that it is about the *actual* cognitive (or physical) processes involved in the mind of a human (or non-human) subject when they engage in reasoning. It is about *inferring* and the form of *inferences* that we make; that is to say, how we draw conclusions from premises.

4.1 Types of inference

There are three key types of inference that are typically employed within scientific research. Some of these are formally valid[pp], others are not. And yet, all three are often applied though at different stages of the broader process of scientific research. Each presents some kind of value in its own way:

4.1.1 Deductive Inference

This form of reasoning starts with a general statement(s), referred to as the premise(s), and examines the possibilities to reach a specific, logical conclusion. If something is true of a class of things in general, it is also true for all members of that class. For instance, "All men are mortal. Socrates is a man. Therefore, Socrates is mortal." If the premises are true ("All men are mortal. Socrates is a man”), then the conclusion is guaranteed to be true (“Therefore, Socrates is mortal"). This is the nature of deductive reasoning.

Figure 3. Deductive inference. The premise of the argument is that all men, such as in this image, are mortal. Further, Socrates (the fellow with his arm raised), is indeed a man. Thus, Socrates must too be mortal… and in this case it is subsequently confirmed when he drinks the hemlock and dies. Image: The Death of Socrates by Jacques-Louis David (1787), reproduced under intellectual commons.

4.1.2 Inductive Inference

In contrast to deductive reasoning, inductive reasoning makes broad generalizations from specific observations. The premises of an inductive logical argument indicate some degree of support (inductive probability) for the conclusion but do not ensure its truth. This form of reasoning often involves patterns and draws a conclusion from observed data. For example, "I've only ever seen white swans. Therefore, all swans are white." This conclusion may be likely based on the observation, but it's not guaranteed.

[pp] Within the field of logic an argument is ‘valid’ if and only if it takes a form that renders it impossible for the premises to be true, and yet the conclusion be false. It pertains only to the structure of the argument though. So, it is not necessary for an argument to actually have premises that are true, only that it must have premises which, if they were true, would guarantee the truth of the conclusion. We will see then that this applies only to certain forms of deductive inference though, whilst they are not formally valid, we can still gain value from other inferential methods.

Figure 4. Inductive inference. The premise of the argument is that you have only ever seen white swans. Thus, you conclude, that all swans are white. But this is not guaranteed from the structure of your argument as even though you have only ever seen white swans, there may still be non-white swans out there you have not seen. Image: White Swan on Water by Yevgen Buzuk (2020), reproduced under intellectual commons.

4.1.3 Abductive Inference

Abductive reasoning starts with an incomplete set of observations and proceeds to the likeliest possible explanation for the group of observations. It involves forming a conclusion from the information that is known. Abductive reasoning is often used in the formation of explanatory theories. For instance, "The lawn is wet. But if it rained last night then of course the lawn would be wet. Therefore, there is reason to suspect it must have rained last night." This conclusion seems to be a reasonable explanation, but other factors could have caused the lawn to be wet (e.g., someone may have used a garden hose, it could be dew condensed from the moisture in the air etc.).

Figure 5. Abductive inference. You begin your argument with the statement that the grass is wet, supported by observation. You consider what sort of explanation would account for this statement. For example, you argue that if it rained last night then it would follow that the grass would be wet. Thus, there is reason to suspect that it rained last night. But this is not guaranteed as other explanations may also be reasonable e.g., the grass was watered by someone using the garden hose. Image: Green grass by Eberhard Grossgasteiger (2020), reproduced under intellectual commons.

In summary[qq], deductive reasoning seeks certainty, inductive reasoning seeks probable generalisations based on past observations, and abductive reasoning seeks the possible explanation given a certain set of observable data. Let us examine each in a little more detail before looking to bring them together cohesively in a holistic description of how they might all find a place in scientific research.

[qq] Here's a nice short video that summarises these three kinds of reasoning and inference.

4.2 Deduction in science

When valid, deductive reasoning in science is where the truth of the premise(s) guarantees the truth of the conclusion(s). Within science its application is often referred to as hypothetico-deduction[53]. Karl Popper[35], who was introduced earlier, was famous for proposing in his *Logic of Scientific Discovery* a particular hypothetico-deductive approach which leveraged a specific form of deductive argument in order not to *confirm,* but to *falsify* scientific theories.

First, let's introduce four forms of deductive argument called implicative syllogisms[rr] involving premises sometimes referred to as theoretical or universal statements (i.e., general explanations or generalisations regarding phenomena and events) and basic statements (i.e., particular empirical observations), and the conclusions drawn from these via reasoning. Two of these are valid forms of deductive inference, whilst the other two are not. Table 3 presents the structure of these arguments (and their fancy Latin names) using the examples of scientific theories (though could also involve generalisations of phenomena e.g., "all men are mortal") and particular empirical observations. Each involves a major premise of the form *if-then*, and a minor premise of the particulars we observe, followed by the conclusion drawn (*therefore*).

Table 3. Examples of deductive arguments

Modus ponens (valid) *If* my scientific theory is a true description of the world, *then* we will observe a particular empirical observation. My scientific theory is a true description of the world. *Therefore*, we will observe a particular empirical observation.	**Modus tollens (valid)** *If* my scientific theory is a true description of the world, *then* we will observe a particular empirical observation. We do not observe a particular empirical observation. *Therefore*, my scientific theory is not a true description of the world.
Denying the antecedent (invalid) *If* my scientific theory is a true description of the world, *then* we will observe a particular empirical observation. My scientific theory is not a true description of the world. *Therefore*, we will not observe a particular empirical observation.	**Affirming the consequent (invalid)** *If* my scientific theory is a true description of the world, *then* we will observe a particular empirical observation. We observe a particular empirical observation. *Therefore*, my scientific theory is a true description of the world.

First let begin with *Modus ponens* which is one of our logically valid forms of deductive argument. The conclusions necessarily follow from the premises. If our scientific theory is true, then it entails that the world works in a particular way and thus we will observe certain things because of that. Now, whilst logically valid, this form of deductive argument is difficult if not impossible to employ in science. It comes back to the epistemic fallacy earlier mentioned in that we can never know for sure whether the initial major premise that our theory is true, is indeed the case.

On the other hand, *Modus tollens*, another of our logically valid forms can be employed and indeed was the focus of Popper's falsificationist epistemology of science. In this form, we similarly assume (albeit tentatively) the premise that our scientific theory is a true description of the world and

[rr] Essentially that their form *implies* whether they are valid or not.

that it entails us observing certain things as a result. Our theory makes certain predictions about the world that we can go out and attempt to observe. But our minor premise is that we do not in fact observe what our theory tells us we should were it true. The result is that we can *reject* the major premise of the truth of our theory and instead say that it is *false.* It should be noted that our theory could entail that there are certain things we should *not observe* and, in this case, if we observed them then it would mean our theory is false. The logical form is the same in this case and in fact it is this that Popper deemed the most severe test of a theory. If the theory 'survives' the test, then Popper argues we can continue to assume (tentatively) that our theory was a true description of the world.

The remaining two forms are invalid, and yet one is still very commonly seen being applied by scientists. With d*enying the antecedent* even if our theory is not a true description of the world that does not mean we will not observe something it entails. There could be other premises (i.e., other theories) that lead to particular observations given that our premise (i.e., our theory) is false. *Affirming the consequent* is the form that most people fall prey to. In this case, whilst we observe what our theory predicts we should observe assuming it to be true, we cannot conclude from observing this that our theory is indeed true. There could be again other explanations for the observations that we make and further there's no guarantees that we won't observe something different in the future. It's worth noting that, whilst affirming the consequent is an invalid deductive form, it may still be an acceptable inductive inference in that it is probable our theory is true. This may be why the form of reasoning is applied so often by scientists.

The forms described above show which are valid, and which are invalid, forms of deductive inference. But, alongside the validity of deductive arguments there is also the soundness of them to consider. An argument is valid if and only if its conclusion(s) follow from its premise(s). Where an arguments premise(s) is true it can be said to be factually correct, though could still be an invalid form of argument (see above). But only where an argument is both factually correct and of valid form do the logicians refer to it as *sound*[ss].

4.3 Induction in science

Despite the strength of deductive logic due to its formal validity ensuring that a conclusion(s) follows from a premise(s), in particular the application of Modus tollens, and the *Problem of Induction* formulated in the 1700s by David Hume, inductive inference is still commonplace in science with many philosophers arguing that scientific inference is inherently inductive[54–57]. As noted, inductive reasoning aims to derive a general conclusion from a set of particular empirical observations and provides not certainty regarding the truth of that conclusion, but only that it is probable.

The key method used to reach inductive conclusions is that of *enumerative induction.* This relies on the *number* of instances of particular empirical observations that support or verify it where the more supporting instances that are found increase the strength of the conclusion. Induction is often claimed to be a mode of reasoning used in the development of scientific theories as explanations from particular empirical observations[tt]; however, as we shall see in the next section this is perhaps more appropriately what is called abductive inference. Inductive inference is largely limited to drawing generalisations about classes of phenomena or events from particular empirical observations and not in building our explanatory theories of them[58]. We might observe 100 white swans and conclude that

[ss] This raises an interesting point with respect to scientific research; if in practice we can only employ Modus tollens as a valid form of deductive argument, but we can never know the facts of the premise regarding whether our theory is a true description of the world, then does this mean that deductive inference in science is valid yet unsound?

[tt] For example, grounded theory, a systematic methodology largely employed in qualitative research, claims to construct hypotheses and theories from the collection and analysis of empirical data.

"all swans are white" or "the next swan we observe will also be white"[uu], but this inductive inference does not aid us in constructing an explanation for why this is the case[vv].

What about in the case of existing scientific theories then? How is induction employed? The form is typically as follows:

> All particular empirical observation so far has matched the predictions of my scientific theory.
>
> *Therefore*, my scientific theory is probably a true description of the world.

Essentially, in the case that we have a theory that makes certain predictions, enumerative induction is used in the seeking of positive instances where those predictions are indeed observed empirically. The more we observe things our theory predicts the more we gain confidence in our theory as being an accurate description of the world. Such confirmation or corroboration though does not ever guarantee the validity of our general conclusions regarding the theory.

4.4 Abduction in science

As has hopefully been made clear, deductive inference is employed in the case of validly testing our scientific theories with the aim of falsification. If the theory fails and we do not observe what it predicts, or we observe things it fundamentally rules out, then we are justified in rejecting it[ww]. When theories pass the tests we make, meaning that our observations match the predictions of the theory, inductive inference is employed to tentatively confirm or corroborate our theory. But, the employ of deductive inference assumes an existing theory to test, and as we have seen inductive inferences do not 'yield' theories as explanations for phenomena or events as the inferences pertain merely to the class of phenomena or events themselves an existing theory might predict. But scientific research does seem to aim at explaining things, going from factual premises, particular empirical observations, to explanations of *why* we have observed them i.e., scientific theories. This type of inference is called *abduction.*

The modern form of abductive inference began with the work of Charles Sanders Peirce who saw abduction as the studying of observational facts, phenomena and events, and the devising of a theory to explain them. It is where our first ideas of *why* something seems to be the way it is come about. The general form of abductive inference as put forth by Peirce was as follows:

> We have the surprising fact (phenomena or event), supported by a particular empirical observation.
>
> But, if a particular scientific theory were true, the surprising fact (phenomena or event) and particular empirical observation would follow as a matter of course.
>
> *Hence*, there is reason to suspect my scientific theory might be a true description of the world.

Here, the scientific theory is understood to be an explanation for why a surprising phenomena or event actually exists. But this surprising fact does not follow from the theory alone. It comes from a combination of the theory and relevant background knowledge used to develop it as an explanation.

[uu] Philosophers seem to have some affinity with matters of an ornithological variety. Take for example the interesting Paradox of Confirmation, or Raven Paradox, formulated by Carl Gustav Hempel which demonstrates a further issue with inductive logic: Observing objects that are neither black nor ravens may formally increase the likelihood that all ravens are black even though, intuitively, these observations are unrelated (see here). Bird is the word.

[vv] This is why the positivists in their application of induction focused upon empirical generalisations and further did not consider causal explanations to be relevant above and beyond the inductive inferences regarding constant conjunctions of events that could be described by general laws.

[ww] Though even this is not quite as straight forward as this in practice. We will touch on this in another chapter [insert chapter link].

Finally, we do not take the theory to be true in this kind of inference, but instead we see it as a plausible candidate for further investigation.

Peirce's abduction was intended to be the first step in generation of scientific theories and after this the application of inductive and deductive inference was applied to confirm or falsify the predictions of this theory. Today it is also quite common to hear the phrase "inference to the best explanation" as synonymous with abduction. Thagard[59] differentiated between three forms of abduction: existential abduction, analogical abduction, and inference to the best explanation.

Existential abduction is primarily aimed at postulating the existence of previously unknown objects. As such it is essentially inference aimed at expanding the category of things included in one's ontology. This in particular includes the existence of currently unobservable theoretical entities (e.g., atoms, forces, dark matter, phlogiston, genes, viruses, fitness, strength, motivation, effort etc.) and these concepts might form part of the broader theories we use to explain phenomena. These postulated entities much like the theories themselves become testable. We can consider the observable consequences that would be entailed by the existence of such entities even if they themselves are unobservable at least at the present time. At some stage they may even be made observable through technological advancements in observational tools. Some may end up passing tests and being corroborated, others may end up in the waste bin of science after falsification.

Analogical abduction, as might seem clear from the name, employs past cases of theorising with similar structure and applies them to new situations i.e., we make an analogy. In essence, where a similar set of phenomena in another field that is better understood exists, then one can "borrow" explanatory principles or auxiliary theories from that field to inform one's own. For example, within sport variations of "periodisation theory" have heavily borrowed from a range of theories in adjacent fields of biology and motor behaviour[60]. Analogical abduction can go hand in hand too with existential abduction essentially saying, "maybe there is a theoretical entity, similar to that in another field, that explains the phenomena we observe here".

Lastly, *inference to the best explanation* is aimed at evaluating competing theories. Although deduction perhaps presents the strongest approach for this comparative purpose where we have multiple competing theories that make opposing predictions, often in science we do not have the benefit of multiple strong theories of this kind. With inference to the best explanation, we instead accept the theory that is judged to provide a better explanation of the phenomena we observe than its rivals do. There have been various suggestions as to what we should use as criteria in judging the best explanatory theory including unificatory power, precision, elaboration of causal mechanisms etc.[61]. Thagard[59] gave a detailed account referred to as The Theory of Explanatory Coherence and more recently Maier et al.[62] developed an account referred to as the Ising Model of Explanatory Coherence[xx]. Recently, abductive inference was explicitly employed in considering causal explanations for the possible performance enhancing effects of differed drugs included on the World Anti-Doping Agencies banned list[63].

4.5 A holistic view of inference in science

Each of the types of inference presented here differ in their forms, and in their targets. Historically, particularly in the case of deductive vs inductive inference, they have been presented at odds with one another in so far as their value in science. Yet, the fact of the matter is that scientists often find themselves in practice employing all three at different times and in different contexts in the process of conducting their research. Figure 6 which has been adapted from Yucel[20] shows a useful framework to assist you in thinking about the nature and dynamic practice of scientific inference in a holistic manner.

[xx] Based on the Ising model of studying phase transitions.

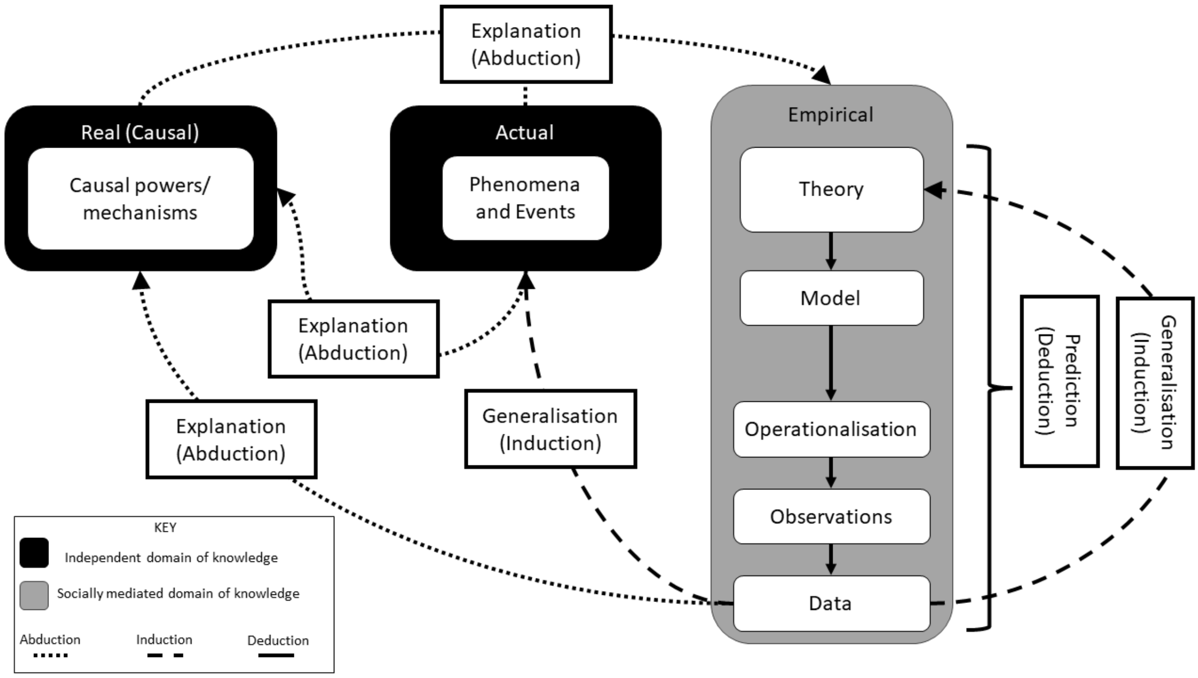


Figure 6. A holistic framework for viewing scientific research and inference (adapted from Yucel[20])

Such holistic approaches to scientific inference are sometimes called *retroduction*, particularly by critical realists[yy]. Figure 6 though does not need to be viewed exclusively from a critical realist perspective, though it lends itself well to it. For example, the domain of the real where unobservable causal powers and mechanisms are posited as explanations might be of interest to the critical realist and the aim of their science; but for a positivist or constructivist this may be seen as off limits and inaccessible for their account of science. The real, and actual, realms are what are considered the dimensions of knowledge independent of the knowledge constructed about them. The empirical realm however is where the socially mediated dimension of knowledge sits, and the knowledge produced and objects within it are influenced by social and personal factors. An anti-realist may see only this part of the framework as being relevant to their science.

The figure gives some insight into the complex and iterative construction of scientific theories. The empirical observations we make and data we produce can be used to abductively postulate underlying causal powers and mechanisms to explain them. We can too inductively infer from these data to make generalisations about phenomena and events, and then further abductively infer from these to causal explanations. These phenomena and events, and/or causal powers and mechanisms, then become the things to be explained by the theories we construct. Our theories entail certain models which we can operationalise in research to produce observations and data. If our theories are false, we can determine this deductively by testing whether their predictions bear out the expected data. If they do bear out, we may then wish to inductively infer that the theory probably is true insofar as it is a description of the actual phenomena and events it explains. We will dig further into the process of theory building and testing in a later chapter [insert chapter link].

[yy] For example, and to lead into a later chapter on methodologies [insert chapter link], see the paper by Mukumbang[64] on retroductive theorising and mixed methodologies.

Exercise: Logic Evaluation in Scientific Claims

Purpose:

The objective of this exercise is to enhance your understanding of logical structures in scientific claims by analysing a specific claim from a scientific article and determining whether it follows a deductive, inductive, or abductive reasoning pattern.

Instructions:

1. Select a Scientific Article:
    a. Choose a scientific article or research paper that contains a clear and specific claim. Ensure the article is relevant to your field of study and complexity appropriate for your current level of understanding. If it is too difficult, try to find a simpler paper and claim to evaluate first.

2. Identify the Claim:
    b. Read the selected article and identify a specific claim or hypothesis presented by the authors. The claim should be concise and clearly stated.

3. Define Logical Structures:
    c. Review the overviews of deductive, inductive, and abductive reasoning above.
        i. Deductive Reasoning: Start with a general statement or premise and deduce specific conclusions.
        ii. Inductive Reasoning: Start with specific observations and infer general principles or conclusions.
        iii. Abductive Reasoning: Formulate the best explanation for observed phenomena based on available evidence.

4. Analyse the Claim:
    d. Ask students to analyse the selected claim and determine which logical structure it follows (deductive, inductive, or abductive).
    e. Consider the language used, the evidence provided, and the overall structure of the argument in making your determination.

5. Provide Evidence:
    f. Provide specific examples or quotes from the article that support your analysis of the logical structure employed in the claim.

6. Discuss and Share Findings:
    g. Discussion your analyses and reasoning for classifying the claim into a specific logical structure with your peers.
    h. Think critically and debate, especially if different students interpret the logic differently.

7. Reflection:
    i. Reflect on the importance of recognizing different logical structures in scientific claims. How does understanding the logic behind a claim contribute to your ability to critically evaluate scientific literature?

5.0 So, what is “scientific research”?

What is this game we call science? The so called “demarcation problem”, how to distinguish scientific work from pseudo-, non-, or un-scientific work, has troubled philosophers as far back as Aristotle[65]. There are both descriptive (what *is* the thing that everyone seems to call “science”), and normative (what *ought* we call “science”) elements to the debates on the topic. Various philosophers have offered ideas on how to distinguish from other activities, some of which we have touched on implicitly in this chapter. For example, the logical positivists verification principle[zz], the falsification principle of Popper, or the epistemic norms of Merton. As you can probably tell by now, there’s hardly a single way to go about playing it. Some such as Feyerabend go so far as saying science is inherently anarchistic in its methods and anything goes[66].

At least at this stage in history, there is no one Scientific Method™ to rule them all[aaa]. You were indeed forewarned of this in the introduction. There is no clear prescriptive answer here for you, only the imperative to think carefully about the various topic presented and how you might seek to apply them to your research efforts. Think about your ontological and epistemological positions. Think about the values you hold and how they influence your research. Carefully apply appropriate logic to the arguments you make, and in interpreting the arguments of others. And remember not to get stuck in dogmatic ways of thinking. There is value to be found in holism and considering the various approaches to knowing that have been discussed.

The rest of this book will also encourage you to do the same. As you read each chapter you should think carefully, critically, and continually reflect on the foundational assumptions that you bring to the table whilst you attempt to play this fascinating game, we call science.

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[zz] Thought strictly speaking this regarded the demarcation between scientific and metaphysical claims.
[aaa] …one Scientific Method™ to find them, One Scientific Method™ to bring them all, and in the darkness bind them; In the Land of Mordor where the shadows lie.

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