SCIENCE AS RELIGION?

SCIENCE COMMUNICATION AND ELECTIVE MODERNISM

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Abstract

My central concern in this thesis is how science should be understood by the public. I argue that science should be understood, and valued for, the formative aspirations of the scientific community. The formative aspirations of the scientific community are the values members try to uphold as members of the group, even when this is not always possible. These aspirations are constitutive of the scientific 'form of life'. I argue that science and religion are distinct forms of life, and through their formative aspirations can be differentiated from one another. Drawing on the theory of Elective Modernism (Collins and Evans 2017), I argue that the formative aspirations of science overlap with democratic values.

Media representations of science shape public understanding. Non-fiction television is a ubiquitous and trusted medium for the communication of science. Non-fiction science television programme makers were interviewed to understand the process of science television production: the pressures, tensions and constraints inherent to this process.

I analyse representations of science in British non-fiction television programmes and argue that a 'religious' portrayal of science can be identified in some programmes. I identify a contrasting 'secular' portrayal of science in other programmes. The religious portrayal presents science as providing a definitive creation narrative. In this portrayal scientific knowledge is presented as a set of certain and immutable truths which are revealed by nature with little or no human intervention. In this portrayal science is presented as providing meaning. The secular portrayal's representation aligns more closely with a sociological understanding of science. In this portrayal scientific knowledge is represented as requiring human skill to produce and as being subject to change, revision and debate. Science in this portrayal is represented as producing both positive and negative outcomes for society.

From the perspective of Elective Modernism, if citizens are to properly understand, engage with and value science they need an understanding informed by sociological conceptions of science which emphasise science's formative aspirations as its defining characteristic. The requirements for the production of an 'elective modernist' portrayal of science, one which foregrounds the formative aspirations of science, are discussed. The problematic consequences of the religious portrayal of science are laid out. Presenting science as a religion disguises its formative aspirations. This provides an inaccurate picture of how science works and a widespread (mis)understanding of science as a religion would undermine democratic society.

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INTRODUCTION
SCIENCE AND DEMOCRACY: ESTABLISHING NORMAL SERVICE

I have faith; not perhaps in the old dogmas, but in the new ones; faith in human nature; faith in science; faith in the survival of the fittest. Let us be true to our time, Mrs. Lee!

HENRY ADAMS, *DEMOCRACY: AN AMERICAN NOVEL*

Invisible Normativity

To act as informed citizens in a modern society, members of the public need to know about science. My central question in this thesis, a question that has troubled researchers throughout the second half of the 20th century, is what *exactly* do the public need to know about science in order to act as citizens of a modern democracy?

What it means for the public to know about science has, historically, meant different things to different people. A public that 'knows about science' in the way required to engage in a democracy is, for some, a public that has detailed knowledge of a range of scientific facts, and can recall these facts on command (Miller 1980, 1983). This knowledge will allow members of the public to successfully navigate a modern society permeated by the products of the scientific endeavour. To others, a public that 'knows about science' is a public that loves science; knowledge of scientific facts inevitably producing an appreciation and respect for the scientific enterprise, an appreciation and respect which will allow science, and as a result the society in which it is embedded, to flourish (Bauer 2007, 2009). For others still, 'knowing about science' in order to act as a democratic citizen means understanding how scientific knowledge is produced. Rather than knowing scientific facts or having a simplistic understanding of the 'scientific method' a public that 'knows about' science knows that scientific knowledge is the product of a defined social group, who through debate and negotiation construct, rather than discover, scientific truths (Yearley 2000a, 2000b; Collins and Pinch 1998). Knowing this will allow members of the public to properly weigh and assess the technical and scientific claims they are presented with in public debates about scientific issues, take appropriate decisions about these claims to the benefit of the society as a whole and, more generally, engage with the scientific process in democratically useful ways,.

This concern with public knowledge of science is built on a dual concern for the wellbeing of both science and the public, a concern rooted in a wider concern for the well-being of society. Fundamentally, concerns relating to public knowledge of science are concerns with how best to organise a techno-scientifically advanced society, one in which, in one way or another, science has become an increasingly dominant institution.

Research into the relationship between science and society is thus inherently normative, without always being explicitly so. Questions about science literacy, public understanding of science or public engagement with science and technology are always questions about the values present in a society, and, to a greater or lesser extent, how a society should be organised. In western democracies in the 20th century at least, concerns about the science-public relationship have been underpinned by a normative assumption about the nature of the relationship between science and the society in which it is located. Science, it has been assumed, is good for society and therefore in order for society to flourish the public must come to understand and appreciate science.

This underlying assumption has justified a number of diverse calls, detailed by Irwin (1995), for increased public understanding of science. Increasing public understanding of science satisfies the requirements of a labour market with an ever-growing number of techno-scientifically centred jobs. A scientifically literate population is required in order to successfully carry out these jobs. By equipping the population with an understanding of science, an institution which has become a central aspect of contemporary culture, more well-rounded citizens are produced. Finally, increasing public understanding of science will produce a population who are better able to act as well informed democratic citizens, and thus maintain the proper functioning of a modern democracy.

As Irwin (1995) shows, this assumption of the goodness of science for society, and the justifications for public understanding of science that follow from this assumption, have been present in the academy since at least the middle of the 20th century, if not earlier. This assumption has underpinned successive movements which attempted to tackle a perceived lack in public understanding of science in order to improve society. The movement for Science Literacy (SL), beginning in the 1960s/70s was one relatively recent movement built on the assumption that science is good for society, and therefore society should be organised in such a way as to be good for science.

Scientific literacy is a measure of the ability of members of the public to recall specific scientific facts. For the SL movement, scientific facts like the boiling point of water, and that boiling water could kill bacteria and therefore make water safe to drink, were the kinds of thing a scientifically literate population would know. According to proponents of the Science Literacy movement (e.g. Miller et al. 1980, Miller 1983), a population that knew these facts and understood the material benefits they provided, would as a result of this knowledge and understanding also come to show appreciation, respect and love for science. The SL movement argued that increasing public scientific literacy, by producing a public that was scientifically literate enough for the emerging labour market and appreciated and supported science, was a way of organising society to benefit science, and thus benefit society itself.

The Public Understanding of Science (PUS) movement, more explicitly pursued this goal of increasing support for science. For some in the PUS movement, this meant pursuing similar goals to those of the SL movement. Increasing public knowledge of science facts was assumed to increase public support for science. To others in the PUS movement, the assumption that "to know science is to love it", was seen as too simplistic. The public were consumers to be wooed using PR tactics. Either way increasing appreciation of, and as a result support for, science was the end goal, a goal which if achieved would guarantee the continued flourishing of society.

As interest in the relationship between science and society developed, the assumptions of the SL and PUS movements were questioned. The Public Engagement with Science and Technology (PEST) movement has been particularly critical of the tendency to assume working to establish a public which is unquestioningly supportive of science is always for the benefit of society. Society, PEST scholars (e.g. Wynne 1992, Irwin and Wynne 1996) argued, would be better organised if science were made to serve, more accountably and openly, the various public groupings and institutions with which it came into contact.

The PEST critique drew on analysis of science provided by scholars in the sociology of scientific knowledge (SSK) and science and technology studies (STS), who since the 1970s, have shown that the set of assumptions about the status of scientific knowledge that the SL and PUS movements were founded on are deeply problematic (Bloor 1991; Collins 1992; Latour and Woolgar 1986). These accounts have convincingly shown that claims to the epistemological primacy of scientific knowledge in comparison to other ways of knowing about the world are difficult to defend. Scientific knowledge, like other forms of knowledge, is a cultural product.

STS/SSK research had shown that scientific knowledge creation was not immune to social and political forces. Science was neither asocial nor ahistorical. Acknowledging this, the PEST movement set out to ensure that science be made as democratically accountable as possible. If politics infused science, it could at least be democratic politics. In practice, this meant opening up such things as scientific funding, and the prioritisation of research programmes to much greater public scrutiny. A shift towards "upstream engagement" was encouraged, where non-scientific stakeholders and other relevant publics were able to set scientific agendas and research priorities in previously unavailable ways (e.g. Rowe et al. 2005). This process, scholars within the PEST movement claimed (e.g. Jasanoff 2004, 2005), would safeguard science against the incursion of undemocratic politics, ensuring that science was able to proceed and continue providing its benefits to society.

The Absence of Normative Justification

What the Science Literacy, PUS and PEST movements fail to provide, however, is an explicit and coherent defence of the normative position (i.e. science is good for society) that are inherent in their divergent projects of either increasing public knowledge of science, or increasing the openness of science to public scrutiny/control.

The claims of the SL and PUS movements that science should be valued because it is the truth making institution *par excellence*, and that the public, by knowing it in this way and knowing its truths, will foster an environment in which science, and as a result society, are nurtured, are undermined by STS/SSK analysis. The SL/PUS claim that the utility of scientific knowledge, stemming from its fundamental truthfulness, is what makes it good for society no longer stands up to critical scrutiny.

The PEST movement also fails to adequately justify the claim that fostering science benefits society. If science is merely politics by other means, it seems unnecessary to single-out science for special safe-guarding. Why should society be organised for science's benefit if science is just like any other institution? The PEST movement claims that science is good for, and should be valued in, society, but is built on an epistemological foundation that undermines this claim. The failure to provide convincing justification for the claim that science is good for society, however, has some potentially negative consequences for both science and society.

If science is understood to be an institution like any other, which due to its fundamental similarity to other institutions is no more entitled to demand special respect for its knowledge claims than any other institution, then it deserves no special treatment. Indeed, the truly democratic thing to do would be to subject science to the same democratic forces to which all other institutions are subject. This would mean that knowledge claims based in science made in the public arena, or policy recommendations made by scientists, would carry no more weight than those knowledge claims or recommendations made from any other institutional perspective.

This equalising of institutional perspectives would lead to those public policy decision in which scientific knowledge was implicated being decided in purely democratic fashion; the position able to garner the support of the largest number of people winning out. Importantly, in the public realm, there would be no legitimate alternative methods of deciding the best course of action in a policy decision in which scientific knowledge was implicated.

It is this state of affairs that appears increasingly familiar in the so-called 'post-truth' political landscape. Science's privileged status as arbiter of truth has been revoked. The normative assumption that science is good for society has been called into question. Indeed, the blame for this is laid at the feet of so-called 'post-modernism' – a catch-all term that points towards the kinds of deconstructionist accounts of science laid out by the SSK/STS and described briefly above (e.g. Calcutt 2016). The deconstruction of scientific epistemological primacy produced the conditions for first the dethroning, and then the defenestration of science. The consequences of science's downfall, though celebrated by some, are for others, this author included, cause for deep alarm.

Restoring Normativity

This state of affairs requires remedying. What is required is a convincing and explicit justification for the normative claim that science is good for society, which is built on firm epistemological foundations. The well-founded and compelling analysis of science provided by SSK and STS must be taken into account, whilst a coherent and robust normative position is provided from which claims about how the relationship between science and the public in society *should* be organised could be made. The new theory of Elective Modernism provides this foundation (Collins and Evans 2017).

Elective Modernism (EM) approaches the science-public-society nexus armed with the insights of STS. Scientific knowledge is understood as essentially contextual, historical, culturally produced and defined. This allows EM to avoid the criticisms levelled at the PUS and SL movements, based as it is on a more empirically justified and sophisticated account of science. However, EM counters the critiques levelled at the PEST approach by retaining a special status for science. STS has shown that science is permeated by politics, this however, does not mean that science and politics are indistinguishable. It is possible to maintain the boundaries between science and politics (and other social activities), and Elective Modernism seeks to do so, by understanding science to be a distinct form-of-life which is defined by a specific set of formative aspirations.

Scientists, as members of the scientific form-of-life, are socialised into ways of being and going on in the world. They are provided with a shared language, set of practices which are carried out and constellation of values which are aspired to when acting as a member of the scientific form-of-life. The values which are aspired to are described as formative aspirations. Formative aspirations are the values that individual members of the form of life attempt to uphold, even though this is not always possible, when acting as members of the form-of-life. Members may not always act in accordance with these values (thus their designation as aspirational) but they will know when they have failed to act in such a way. This language, set of practices and aspirations demarcate science from other forms-of-life.

EM claims that the formative aspirations that guide science include aspirations (such as those to observation, corroboration, falsification, empiricism and the valuing of expertise) that are the best (though not perfect) aspirations to follow when attempting to produce knowledge about the world. Though these aspirations are not always followed, that scientists attempt to follow them in the production of scientific knowledge makes science a *better* activity for producing knowledge than activities guided by other aspirations. It is fundamentally important to understand that the claim that science is a *better* activity for producing knowledge does not mean science produces more reliable or more truthful knowledge. The aspirations by which scientists are guided make science *good* in a moral sense. Scientists are valued for aspiring to observe the natural world because observing is a *good* (in the moral sense of the word) thing to do (Collins and Evans 2017). There is no deeper foundational philosophical justification for this position. It is possible to not accept that these aspirations are good aspirations to aspire to in order to find things out about the world. In this way the claim of EM is propositional. EM's proposes that these values are accepted as self-evidently good, and this claim is reinforced when alternative aspirations are considered. In this way, EM retains the special status of science whilst the acknowledging the epistemological critique levelled at science by STS/SSK.

Elective Modernism, however, goes beyond arguing that it is the formative aspirations of the scientific community which define science and in that attempting to uphold these values in their knowledge production scientists produced knowledge *better* than that produced in other forms of life. EM argues that many of the formative aspirations of science (such as those to universalism, disinterestedness, communalism, organised scepticism, honesty and integrity) are exactly the kind of values that a democratic society should aspire to uphold. The formative aspirations of science mean that science is also a normative cultural resource. Science, EM claims, is a paragon institution in a modern democracy, a form-of-life organised around a set of aspired to values which when upheld guarantee many of the freedoms and protections that individuals would expect in a democracy.

A society guided by the formative aspirations of science would resist both unthinking, uncritical acceptance of science as well as its opposite, complete disregard for scientific thinking. Scientists, amongst other aspirations (detailed in tables 1 and 15 in chapters 1 and 8), are guided by the aspiration to organised scepticism; the development of a critical frame of mind or attitude towards all knowledge claims. This is not an unbridled cynicism in the face of new knowledge, but a desire to interrogate new claims before accepting them. Accepting things on trust, or on the authority of those making the claim is, at least in terms of the aspirations of science[1], anathema to scientists, as it would be to a society guided by the formative aspirations of science. Claims made from those with perceived authority would therefore be subject to the same scrutiny as claims made by those who lacked authority.

However, by the same token, scientists aspire to value the expertise of their fellow scientists. They believe that long experience and training provides firmer ground from which to make knowledge claims than does a comparative lack of training and experience. Those who possess more experience and knowledge are better listened to than those who lack it. A society whose aspirations aligned with those of the scientific community would share a similar respect for expertise. This would help the society to resist some of the worst excesses of populism, where anyone's word is as good as anyone else's, and all decisions are decided based on the majority opinion.

Elective Modernism therefore offers a way to navigate between the extremes of the 'post-truth' radical undermining of popular regard for science which can claim intellectual foundation in STS/SSK critiques of science and the epistemically baseless respect for science identifiable in the SL/PUS/PEST approaches. This is based on a choice (thus elective) to view science (thus modernism) as an exemplary institution to which a modern democratic society should also look for normative guidance[2].

[1] Of course, as e.g. Mitroff (1974) has shown, scientists very often take the claims of those in authority more seriously than those who are not in authority. Authority in science is often a result of perceived expertise or level of knowledge, and scientists aspire to take each other's expertise seriously. However, scientists do not aspire to believe the claims of an authority figure simply because they are in authority, to do so would be to not act in accordance with the formative aspirations of the scientific form of life.

[2] It is important to note that EM does not claim that only science should provide the normative guidance in a modern society. Science has little to say on issues of beauty, art or justice. Therefore, a society would need to look beyond just the aspirations of science for normative guidance.

The analysis presented in this thesis is founded in this normative perspective. It is this normative perspective that compels me to concern myself with television representations of science. These representations of science have the power to shape publics' understandings of science. As such, those representations which may work to produce public understandings that are not conducive to the goals of Elective Modernism, or which actively work against these goals, I will critique. Thus, it is from this perspective that I draw attention to the religious representation of science I identify in chapter six.

In programmes which employ a religious portrayal, science is portrayed as producing certain and immutable knowledge of all aspects of existence. A creation story, which locates humanity at the pinnacle of creation, is provided by science when represented this way. Represented as complete and definitive, science provides the foundation upon which a meaningful ordering of the world can be constructed. This portrayal misrepresents science. This representation disguises the formative aspirations of the scientific community and thus, I argue, has the potential to produce a public which does not understand that it is formative aspirations that define science and can provide normative guidance in a modern democracy. The religious representation therefore jeopardises the increasingly important and timely work of the Elective Modernist project.

I will compare this portrayal of science with a secular portrayal. In this portrayal scientific knowledge is represented as uncertain and provisional. Represented in this way, scientific knowledge creation requires technical skill and participation in an expert community. The consequences of scientific research can be difficult to predict, and be both harmful and beneficial for society in the secular portrayal. This is a more accurate representation of science. It more closely reflects the processes by which scientific knowledge is created and the epistemic status of scientific knowledge. This portrayal, with slight modification to emphasise the formative aspirations of science, would communicate science in a way which would be beneficial for a democratic society.

The programmes which portray science in these different ways are products of a system of production. The production of a non-fiction science television programme involves a number of people arranged in a complex hierarchy. Individuals occupying different positions in this hierarchy have different goals for the programmes, experience different pressures and are constrained by forces of institution, profession and genre in different ways. Television programmes are a product of this matrix of institutional, professional and relational forces. Understanding this system of production and the tacit and explicit rules which govern the individuals working within it gives rise to explanations of the provenance of the religious and secular portrayals of science. It also gives rise to recommendations as to how this system of production could be modified in ways which would reduce the likelihood of the appearance of the religious portrayal of science and promote production of representations of science which emphasise the formative aspirations of the scientific community as being science's defining, and democratically beneficial, characteristic.

Research Questions

In this thesis, I will answer the following research questions:

1) How are non-fiction science programmes made? What are the processes involved in the production of non-fiction science television programmes? What are the institutional, professional and genre constraints non-fiction science programme makers are subject to and how do these influence the 'model of science' programme makers adopt and communicate? How do this model and these constraints lead to the production of particular representations of science, which I describe as either secular or religious?

2) What are the characteristics of the secular and religious portrayals of science, and how do these portrayals manifest themselves in the different programmes analysed?
3) Is there the potential for the religious representation of science to provide a religious function for a subset of its audience? Is it feasible that, in a modern 'mediatised' society, the religious portrayal of science could act as collective representation through which a group of individuals could find meaning and a sense of solidarity with one another?
4) What are the consequences if science is understood as, and potentially functions like, a religion? Is this conducive to the proper functioning of democracy? If not, how can this be avoided, and an understanding of science which is conducive to the proper functioning of a modern democracy promoted via television representations of science?

Structure

In chapter one I will define science and religion. I will argue that science and religion are distinct 'forms of life' (Collins 1992). The knowledge and understanding of the world produced by both are products of social groups. Though similarities between science and religion are identifiable, I differentiate the two through comparison of their formative aspirations. The formative aspirations of a community are the values which members of the community aspire to uphold, even if they are not always able to act in perfect accordance with these values. In this sense the values are intentional or aspirational (Collins and Evans 2017).

In chapter two I will present an overview of the science communication literature. I will trace the historical development of different approaches to public communication of science; science literacy, public understanding of science (PUS), public understanding of the process of science (PUPS) and public engagement with science (PEST). The public understanding of the process of science (PUPS) movement stresses the need for publics to be aware of the social and cultural process which underpin scientific knowledge creation. To properly understand and democratically engage with science the public needs to understand these processes (Collins and Pinch 1998). I will then discuss the impact of mass media representations of science on public understanding. Though the relationship between media representation and audience understanding is complex, I will argue that media messages can have identifiable impacts on audience perceptions, understandings and attitudes

In chapter three I will outline my methods. Ethnographic content analysis was employed to investigate in detail the representation of science in two non-fiction science television programmes. This analysis was complemented by semiotic theory. Television programmes create meaning through various modes; talk, image, soundtrack. Analysis of all these modes, and an understanding of how taken together they create a complex semiotic system which conveys a richness of meaning is required when analysing television content. Alongside this content analysis, I explored the world of science television production to understand how and why these different portrayals of science come about. Through interviewing members of the community of non-fiction science television makers I intended to gain "participant comprehension" (Collins 1984). Interviewing was a proxy for a lengthier embedding in this community. I will provide an account of the spaces and places in which my interviews were conducted and how this may have influenced the data I collected. I will discuss the ethical issues I faced during this research, focusing on the potential problems with maintaining confidentiality in a small community and the contrasting needs of researcher and participant.

In chapter four I will provide a sketch of the process of producing a non-fiction science television programme. I will describe the four stages of production; development, pre-production, filming and post-production. I will describe the various roles that are involved in this process, when these roles are most influential and what responsibilities each role carries. This will help to contextualise the more detailed analysis presented in chapter five.

In chapter five I will describe the knowledge, pressures and aspirations which constitute the world of specialist factual science film-making. Television programmes must attract as large an audience as possible. To ensure an audience is engaged, television programme makers tailor their programmes to cater to their audience's perceived desires. Different times of day, and different channels attract different audiences, who are engaged in different ways. Programme makers must produce a variety of programmes to meet this variety of demands. Specialist factual science film-makers must balance this demand for engagement against the pressure to faithfully represent scientific reality. The programmes they make are non-fiction and so must have some basis in reality. In order to faithfully represent reality and engage different audiences, film-makers adopt different programming styles. Long-form expository documentary is a format which is adopted to engage a specific audience. Expository documentary abstracts away from day-to-day reality. To make these programmes engaging, film-makers borrow narrative structures from fiction. These narratives are closed-ended and definitive. These formats facilitate a religious portrayal of science. To engage different audiences shorter-form programmes are made. The ability to develop cohesive long-form narratives is limited in these shorter-form programmes. These programmes can engage their audiences through showing the relevance of science to everyday life, or by focusing on new and topical science. These formats facilitate a secular portrayal of science. Science film-makers adopt the 'canonical model of science'. They believe that communicating science to as wide an audience as possible is a good thing. They understand that their programmes are ill-suited to communicating detailed scientific information, but they believe that they can engender positive public attitudes to science. This understanding of science, and this promotional goal, allows for the production of uncritical representations of science such as the religious representation.

In chapter six I will present my analysis of two non-fiction science television programmes; *Wonders of Life* and *Bang! goes the Theory* first broadcast on the BBC in 2013. I will describe the characteristics of the secular and religious portrayals of science. These will then be illustrated through first a detailed analysis of representation of DNA in episodes of each programme. Through further examples I will show how *Wonders of Life* overwhelmingly presented a religious portrayal of science, and *Bang! goes the Theory* overwhelmingly presented a secular portrayal.

In chapter seven I will discuss the function of the religious representation of science within modern British society. Drawing on the concept of 'mediatised rituals' (Cottle 2006) I will argue that collective effervescences which promote religious sentiment are possible in mediated societies. I will discuss the possibility of the religious representation of science acting as a collective representation around which a sub-group of society can come together. New habits of audiencing (Social TV, second-screens) will be suggested as facilitating this coming together and acting to reinforce solidarities. I will show how some TV makers are actively involved in producing 'creation tales for atheists' to potentially satisfy this sub-group's demand for a collective representation. I will provide indicative evidence that the religious representation of science can act as source of nomisation (Berger 2011) shielding individuals from anomic phenomena.

In chapter eight I will outline the potential problems of a solidarity based around the religious representation of science. The *Society of Sacred Science* will be described. This is a society that is built around a religious understanding of science. Drawing on the work of Marcuse (2002) I will show how this society could potentially limit individual freedom and autonomy. I will suggest ways in which the sanctification of science can be avoided. Employing different film-making techniques could curtail the production of the religious portrayal of science. Employing these techniques would encourage the adoption of a more contextual model of science amongst film-makers which would further help to curtail the appearance of religious representation of science. Finally I will describe an elective modernist portrayal of science. Elective Modernism views the formative aspirations of the scientific community as aligning with democratic values. Science understood as defined by these aspirations, rather than as presented in the religious portrayal of science, could form the basis for a more democratic solidarity.

CHAPTER 1
SCIENCE AND RELIGION

> *"The trouble with the world was... that people were still superstitious instead of scientific. He said that if everybody would study science more, there wouldn't be all the trouble there was."*
>
> KURT VONNEGUT, *CAT'S CRADLE*

Science is frequently defined in opposition to religion. Science is said to produce justified true belief through its rational and empirical method, whilst religion is characterised by untestable, non-empirical beliefs. But observation of the intellectual and working practises of science shows that there is no universal, algorithmic 'scientific method'. Scientific knowledge is a product of the social, as well as the natural world. At the same time, definitions of religion which pertain only to religious belief fail to address religion's social function. Religion is a social product, which functions to bind individuals in a community to one another, and allows them to make sense of their experience of the world.

I will define science and religion as different 'forms of life' which are differentiated by their formative aspirations. The formative aspirations of a group are the values that group members aspire to uphold and the actions they attempt to carry out in upholding them. It is not always possible for group members to behave in accordance with the formative aspirations of the group, yet the aspirations remain constitutive of the form of life. Group membership shows individuals how to think and act, even if they cannot always mange it. The religious and scientific forms of life have different formative aspirations. The scientific form of life is constituted by the aspiration to the open-endedness of (all) knowledge, the aspiration to empiricism (observation, corroboration, falsification), the aspiration to generality of explanation and the aspiration to scepticism. In contrast, the religious form of life is constituted by the aspiration to closed-endedness of (some) knowledge, the aspiration to anti-empiricism or revelation, the aspiration to total generality of explanation (world-ordering) and the aspiration to faith.

These are the formative aspirations which contrast most obviously where science and religion are concerned. There are other aspirations, some of which are shared by both.

Defining science and religion in this way allows me to describe science as sometimes being represented as a religion. I will argue that presenting science as religion involves representing science as if it was constituted by the formative aspirations of the religious community. This includes presenting scientific knowledge as definitive or unchanging, presenting scientific knowledge as being revealed with little human intervention in the world, presenting science as being able to explain all facets of existence, as being able to provide an overarching creation narrative and as being able to provide meaning and justification for existence.

Science

> "Scientists and others tend to believe in the responsiveness of nature to manipulations directed by a set of algorithmic-like instructions. This gives the impression that carrying out experiments is, literally, a formality. " (Collins 1992, p. 129)

Scientists generally understand science to be fundamentally asocial and ahistorical. They view themselves as acting in this way in their scientific work, and this view of science is common outside of the scientific community. This is described by Collins as the 'canonical model of science' (Collins 1992).

Under the canonical model of science, human intervention or interpretation is kept to a minimum during scientific knowledge creation. Science is a rule-bound, 'algorithmic' procedure where new knowledge is created by scientists following a set of logical procedures that are or can be entirely pre-scripted. The empirical experimental method is the defining characteristic of science, with replicability of experiments being the process by which new knowledge is established (either through confirmation or refutation depending upon the outcome of the replicating experiment). When conducting experiments, scientists are rational operators of specific and specified laws, abiding by a strict, logical method to produce either positive or negative results. Through following these procedures correctly, new scientific facts are created in unproblematic ways. Under this view "facts speak for themselves to unbiased observers" (Collins 1992, p.164).

There are fundamental problems with the canonical model of science. Defining science in reference to empiricism exposes science to the "problem of induction". The problem of induction stems from the unreliability of empirical sense data. David Hume argued that it is in principle impossible for us to know that previously observed regularities (i.e. swans being white) will continue to occur in the future. Hume's sceptical position argues that it is in principle impossible to know that our sense data, or our perception of the world is a completely reliable predictor of the future. What we have previously perceived as white objects may turn out to be black tomorrow. Based on our sense data, we have no way to know what today's colours imply about what we will see in tomorrow's world (Goodman 1973). This line of argument can be traced back to, for example, Descartes, who argued that our experience of the world could in fact be the work of an evil demon introducing experiences directly into our minds. Defining science in reference to empiricism exposes science to this sceptical critique. In fact, this criticism can be levelled at any account of human understanding that is built on perception of the exterior world (i.e. all accounts of perception).

However, this seemingly intractable problem of induction has little impact on how scientists go about creating scientific knowledge. Scientists in their everyday practises go on as if external sense data was reliable and previously inferred regularities will continue to exhibit the same traits in the future.

The canonical model does not account for how scientists are able to overcome the problem of induction. It does not accurately describe how scientists actually behave when doing science, and how the practices of scientists establish scientific knowledge. Scientists do not abide by strict, well-formulated and expressible rules in the labour of scientific knowledge creation. However, they draw conclusions from their work and these conclusions are accepted by many scientists and presented to the world as stable facts. The, in principle, problem of induction is constantly overcome in practise as it must be if we are to have a science or any other kind of stable observations in our world.

To understand how the problem of induction is overcome in practise, by the public in general or scientists specifically, an anthropological approach is required. Scientists must be viewed as members of a community who through their shared activity produce stabilised knowledge of the world, which appears to other scientists as reliable knowledge, and is presented to non-scientists as hard facts. The methods by which this is achieved are of primary importance and to understand how this occurs, an understanding of how science works on the social level is required.

> "The concern is not with how we could be certain in principle about induced regularities but about how we actually come to be certain about regularities in practice." (Collins 1992, p. 6)

Wittgenstein and Forms of Life

For Wittgenstein, the ways in which groups shape how individuals behave can be explained through understanding what occurs in the case of an individual being asked to follow a rule[3]. When an individual is presented with the sequence '2, 4, 6, 8' and asked to carry on in the *same* way, there are almost limitless possibilities as to what can count as the correct answer. Though '10, 12, 14, 16' may appear to be the 'correct' answer, equally

[3] The following example is a condensed version of that presented in (Collins 1992 pp. 12-14)

legitimate under the instruction to go on in the same way would be '2, 4, 6, 8, 2, 4, 6, 8' etc. However much more detail is added to the initial instruction, there are still legitimate responses that do not give the 'correct' answer. For Collins, this reveals a number of things:

> "The game shows that first, rules do not contain the rules of their own application. Second, the notion of 'sameness' is ambiguous. Third, it is not possible to specify fully a rule or 'algorithm' for action in an open system (one where creativity is possible), since if a limited range of responses is not defined in advance then more than one response which satisfies the algorithmical instructions can always be invented... Fourth, since in spite of this we all know the correct way to go on, there must be something more to a rule than its specifiability" (Collins 1992, p. 14)

This 'something more', which allows us all to know the correct way to go on is social convention. It is possible for us to provide the right answer, to follow the rule correctly, as the social group we are members of, or the 'from of life' we inhabit, provide us with ways of going on in the world which are shared.

> "The rightness of 10,12,14,16' as the continuation of '2,4,6,8,' resides in its rightness for everyone sharing our culture" (Collins 1992, p. 15)

When we make a mistake in going on in a form of life, we are corrected by other members of the form of life, and thus we learn the correct and incorrect ways of going on in the groups we inhabit. For scientists, the correct way to go on in their form of life is believing in such things as reliability of empirical sense data, the continuity of previously observed regularities and confirmation or falsification of theory through replication or non-replication. If a scientist claims to have proven a theory because they have received divine communication confirming their claims, their mistake will be pointed out, and their argument will not be taken seriously. They will have failed to go on in a way acceptable to the form of life of science.

Certain beliefs can be generally held to be true (e.g. a relativistic universe) and other beliefs (such as the sun, planets and stars orbiting the earth in a set of nested crystalline spheres) are generally rejected, but only within a common set of conventions that hold the form of life together at any given time.

Bloor developed this point in the 'strong programme' of sociology of science. Drawing on the work of Wittgenstein he suggests that both 'true' and 'false' scientific beliefs should be explained by the same mechanisms. A specific belief being seen as false and another as true should be seen as partly the result of social processes within which the establishment of certain ideas as plausible and acceptable, and others as implausible takes place[4]. Bloor (1991) suggests that the 'principle of symmetry' must be used in explaining scientific belief.

> "Bloor writes that his "equivalence [i.e. symmetry] postulate ... is that all beliefs are on a par with one another with respect to the causes of their credibility. It is not that all beliefs are equally true or equally false ..." (1982: 23). In other words, Bloor holds that in the case of all scientific beliefs – true or false – we should seek sociological (partial) explanations for why they seemed credible to their advocates. But this does not mean that Bloor has any tack with the thought that all beliefs are true, or all beliefs are false." (Kusch 2012, p. 173)

As the above quotation suggests, Bloor was not arguing for a radical epistemological relativism. Rather Bloor's focus is on why certain knowledge

[4] The exact process by which beliefs come to be seen as true or false is detailed in such texts as Collins (1992), Bloor (1991). What is important to note for my purposes is that the settling of any scientific debate which leads to the creation of new knowledge requires 'non-scientific' factors. The natural world does not speak for itself – who becomes natures spokesperson, whose interpretation wins out, is always the result of social factors.

at certain times is held or believed to be true, or in other words, how truth is achieved in practice, rather than in principle.

Holding certain beliefs, and rejecting others, becomes part of the 'natural attitude' of scientists. Collins suggests that scientific facts become 'taken for granted' when they form part of the shared social and cultural institutions of science. What is important is that the source of 'natural attitude', because of its 'taken-for-grantedness', becomes very difficult to identify. It is hard for the individual inhabiting a form of life to see that their perceptual order is the product of a set of shared (social) conventions (Collins 1992).

Because of this, when scientific beliefs become reified, their social provenance becomes very hard for the scientist (or anyone except the committed sociological observer) to recognise. Only rarely are scientists involved in the 'extraordinary' phase of science where new knowledge is created through 'non-scientific' social processes. After-the-fact, those elements which were 'non-scientific' are quickly forgotten and made to appear (and even appear to those scientists involved) as the outcome of the canonical model of science (Collins 1992).

Recognising science as a cultural activity akin to any other is therefore even more difficult for the non-scientist as we have no direct experience of the process by which scientific knowledge is created. Scientific knowledge comes to the non-specialist stripped of its cultural trappings. In the language of Collins – the core set (those involved in the creation of a new piece of scientific knowledge) 'launders' scientific knowledge, so it appears to be the product of a set of logical, explicit, rule-guided steps. Non-participation in the inner workings of scientific knowledge creation renders these inner workings invisible and the knowledge that results from it more authoritative, a-cultural and ahistorical. As Collins puts it "distance lends enchantment".

> "Why is it that the view of science as a human product is so difficult to maintain? I have already argued that the privacy of the core set provides the particular answer in the case of

> science. Scientific training forces the experience of nature's caprices to be interpreted as personal failure thus understressing the human contribution to the achievement of conceptual order" (Collins 1992, p. 167)

It is for this reason that the canonical mode of science is so prevalent. When engaging in scientific work, scientists perceive science as it is described by the canonical model[5]. They believe that they are following a set of logical and clearly formulated instructions to achieve well specified ends (e.g. replication of an experiment). When the results of science are offered to those who do not inhabit the form of life, they appear to those non-members as the product of a logical, algorithmic process.

If the veneer of the canonical model is peeled back, the inner workings of science are visible. These inner workings resemble the inner workings of most other forms of life. Scientists possess a 'natural attitude' to their 'taken for granted' reality, as do people in any culture. This is the only way in which scientists can go about the work of science. They are not being 'unscientific' when entering into social negotiations to close a debate, they are participating properly in their form of life. As Collins puts it:

> "Scientists do not act dishonourably when they engage in the debates typical of core sets; there is nothing else for them to do if a debate is ever to be settled and if new knowledge is to emerge from the dispute. There is no realm of ideal scientific behaviour. Such a realm – the canonical model of science – exists only in our imaginations" (Collins 1992, p. 143)

It remains possible to draw a distinction between the scientific and other forms of life. The practises undertaken within and the values which underpin

[5] Some scientists are able to recognise the social provenance of scientific knowledge. In order to participate in the work of science, however, they must compartmentalise this knowledge, and view science in the naïve realist terms of the canonical model. These scientists are described by Collins and Evans (2017) as "Owls"; they are able to look both ways. Depending upon context they are able to see scientific knowledge as both the product of rigorous empirical method and social negotiation.

these forms of life can demarcate one from the other. Clear differences between one form of life and another can be identified in this way. Robert Merton identified some of the demarcating values held within the scientific community.

Merton's Norms and Wittgenstein's Formative Aspirations

Merton (1973) argues that the scientific community is organised around the values of communalism, universalism, disinterestedness and organised scepticism. Communalism suggests the open sharing of knowledge amongst the community. Universalism suggests allowing anybody, regardless of gender, race or creed to practise science, and the judging of the quality of scientific work based solely on its scientific credentials, not these other extraneous factors. Disinterestedness describes the quality by which scientists work in the pursuit of scientific knowledge for the sake of that knowledge, not for personal fame, fortune or glory. Organised scepticism is the mentality with which scientists approach the results of their own and others work – questioning and doubting findings and theories until they have been rigorously and repeatedly shown to be correct.

Merton suggested that there is a normative pressure felt by individual scientists working within the scientific community to act in accordance with these values. If individual scientists fail to do so, in Merton's eyes they are failing to carry out proper science and knowledge arrived at in violation of these norms should be considered unreliable scientifically.

However, in direct contradiction to Merton, Mitroff (1974) described a set of counter-norms that were identifiable in the practise of scientists; selfishness, secrecy, glory, fortune or fame hunting and credulity in respect to results (particularly those of scientists with prestigious reputations). These counter-norms influenced the conduct of practising scientists and impacted on what became established as scientific knowledge.

It seems difficult to reconcile these claims if thought of in terms of the normative influences. It is hard to believe that a person can be simultaneously guided to behave in an open and a secretive way, or be simultaneously credulous and sceptical. The solution to this problem is to view these normative commitments or values as aspirations. Rather than describing the way scientists always behave, Merton's CUDOS values can be viewed as being the values that the scientific community aspires to uphold, that individuals within the community aspire to follow even if this is not always possible. These values can instead be viewed as formative aspirations (Collins and Kusch 1998). In this way, it is possible to reconcile both the observations of Merton and Mitroff. In his work on space science Mitroff may well have seen scientists acting secretively, or paying lip service to high profile colleagues. These scientists would have been engaging in activity that contravened the aspirations of science. Importantly however, to use the language of Collins and Kusch, these action tokens would not be representative of the formative action type of science.

> "Scientists may cheat, lie, and act in self-consciously politically-biased ways without destroying the notion that the aspirations that are constitutive of science's form-of-life do not include cheating, lying, and doing science in a self-consciously politically biased way" (Collins and Evans 2017, p. 34)

Alongside Merton's CUDOS values, are a number of other aspirations. These include viewing scientific knowledge as provisional and emphasising the maintenance of the Kuhnian 'essential tension' between the consensus and individual innovation (Kuhn 1962). Though scientific knowledge is the product of consensus, there must always be space allowed for individual revision or rejection of settled ideas as this is how scientific knowledge can progress. A list of the formative aspirations of the scientific community is presented in Table 1, which draws on the scheme presented in Collins and Evans (2017).

FORMATIVE ASPIRATIONS OF SCIENCE
Observation: finding things out through looking at the world
Corroboration: repeated looking means more evidence/support for theory
Falsification: claims should be open to being disproved – how this could occur should be set out
Organised Scepticism: claims must be open to criticism, and community must question new claims (doubt in spite of belief)
Open-endedness: science isn't finished or certain/definitive
Generality: the wider the application of a theory/idea the better
Locus of Legitimate Interpretation (small, centred): those best positioned to interpret sci. knowledge are closest to its production (other core-set scientists) – opposite to arts
Clarity: attempt to convey information so it is only interpretable in the way the conveyor intends
Universalism: science open to all regardless of gender, creed, sexuality. People judge on quality of their scientific practise
Disinterestedness: science done not in service of own gain or with overt political ends
Honesty and Integrity
Continuity: new knowledge produced should try and fit with that already conceived – revolution should be reluctantly undertaken
Expertise: valuing the contribution of people who know what they are doing and what they are talking about – not just people who are credentialed/in authority (though it is difficult to separate the two)
Essential Tension: individual can find things which go against mainstream understanding, and eventually overturn it

TABLE 1

A form of life is not only demarcated from others by its formative aspirations. As well as being defined by the aspirations of the community, science is also defined by its practises. As well as sharing a set of formative aspirations, scientists share a set of both bodily and linguistic skills which demarcate their community from others. Within the scientific community, these skills will demarcate one scientific discipline from another. These bodily and linguistic skills provide scientists with substantive expertise.

Expertise

This substantive element of expertise is embodied in the tacit knowledge possessed by members of a community and arises through immersion within and socialisation by a specific community of experts (Collins and Evans 2007). Assessing who has expertise is a matter of assessing the levels of socialisation within an expert community an individual has, their ability to walk the walk, and for those immediately outside the discipline, “walk the talk” (Collins 2016) of that specialist group. Practise languages are those technical vocabularies that differentiate expert groups from one another (Collins 2011). Mastery of the practise language indicates at least interactional expertise[6] within that group. What this means in practise is that expertise is a much more ubiquitous property than was previously considered. Cricket players have expertise in the practise language of cricket, in the same way that gravity wave physicists have expertise through their mastery of the practise language of gravity wave physics.

Identifying a practise language is a way of identifying an expert group. However it is not only expertise which demarcates groups. Expertise is a ubiquitous property, and expertise and science are not necessarily synonymous (e.g. expert cricketers). Alongside the specific language and practice expertise, the formative intentions of the scientific community are what characterise the practise of science and demarcate it from other forms of life.

Religion

Religion is a contested term. It has been described as a secular, western, academic concept which in its use elides and modifies that which would be its object of study (Smith 1963; Barth 2006). Counter to this, Luckmann (1967)

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[6] Interactional expertise is a concept developed in detail by Collins and Evans (2007). Collins (2016) defines the concept as follows:

> “Interactional expertise is one of two kinds of specialist expertise that depend on possession of the tacit knowledge of the specialist domain. The other, ‘contributory expertise’ is what we normally mean when we talk of experts—these are people who exercise their expertise by contributing to their specialist domain…[interactional] expertise is more than ‘talking the talk’ while not being able to ‘walk the walk’ because it is a kind of expertise that enables one to make sound technical judgments that pertain to the domain: it is best thought of as ‘walking the talk’.” (Collins 2016)

Interactional expertise can be gained by long immersion in the discourse of a specialist community. Without possessing the practical, embodied skills to contribute to the domain, an interactional expert can still hold relevant and informed technical conversations with contributory experts, which importantly can inform the practises of the domain.

suggests that the term religion is wedded too closely to specific, Christian forms of organised religion and ignores or renders invisible other forms of religious activity. The term religion can be interpreted flexibly, allowing religion to be defined in reference to a diverse set of characteristics.

> "The difficulty of definition arises from the fact that [religion] is not an indexical term but a general concept which directs attention to complex constellations and aspects of social and material relations for certain purposes" (Woodhead 2011, p. 121)

A pragmatic solution to the problem of defining the term religion is offered by Woodhead (2011). Critical and conceptual self-awareness is required when using the term religion. Any use of the term will point towards certain groups, practises, beliefs or identities whilst ignoring others. Those aspects of reality which a definition intends to capture are not the only aspects that the term religion could apply to, nor are they aspects that another conceptualisation would necessarily define as religion or religious.

> "It is necessary to have some critical awareness of what concept(s) of religion are in play, and to be able to justify their applicability in particular contexts of use…It may be possible to justify [a] concept of religion, but in order to do so it is necessary to be able to show why it is appropriate within the research design as a whole. And in order to do that, it is vital to have some sense of the alternative concepts which could be employed" (Woodhead 2011, p. 122)

My conceptualisation of religion is constructed from five complementary elements. These elements are separated into two themes, the first of which defines religion in reference to its form, the second of which defines religion in relation to its function. The elements of my conceptualisation of religion are detailed in Table 2.

My Conceptualisation of Religion	
Form	**Function**
Religion as content of belief	Religion as communal product
Religion as quality of belief	Religion as force of nomisation
	Religion as producer of solidarity

Table 2

As with my definition of science, I will conceptualise religion as a distinct cultural form. Religion is a social product which can be defined both in reference to the function it provides within a society, and the specific form it takes. The quality and content of the knowledge, understanding and attitudes it produces amongst those individuals who adhere to it, can define something as a religion. Beliefs which unite individuals together and allow them to make sense of their experience of the world are religious

The Religious Form: Content & Quality of Belief

> "Being religious has to do with believing certain things, where that amounts to subscribing to certain propositions and accepting certain doctrines" (Woodhead 2011, p. 123)

Religion can be conceptualised as primarily concerned with belief. The what, how and why of a belief can define it as religious or non-religious. What is believed, the identified source and strength of belief can be enrolled in definitions of religion.

Historically, religious doctrines contain non-material or anti-empirical explanations for phenomena. Religious belief directs attention away from the human realm of existence. Non-human, supernatural, or spiritual beings, entities or forces are enrolled in explanation of phenomena.

> "The content of belief is further specified in definitions of religion: for example, belief in the existence of supernatural beings or forces" (Woodhead 2011, p. 123)

Not only are these beings, entities or forces responsible for experienced phenomena, explanations of the world are given to man by these supernatural entities. This is characteristic of a great range of religious belief. To understand who is bewitching him, the Azande consults the poison oracle, who speaks to him through his fowls. Though this is an entirely rational activity for the Azande, the explanations he seeks come from a non-human realm (Winch 1964). Christians believe that Moses was delivered the Ten Commandments on Mount Sinai by God, and other writings in the Bible were delivered by God to prophets who subsequently communicated God's words to his people. For Christians the Bible is the "Word of God", not only does God exist, but awareness of his existence and human understanding of it is communicated directly to humans by God[7]. Religious belief is both concerned with, and founded in, supra-human explanations of the world.

These supra-human realities and explanations are figured into complete, overarching accounts of the world in the form of creation narratives (Hopfe and Woodward 2008). Creation narratives provide a complete and definitive account of the how the world/universe/life came into being and subsequently how the world is and should be ordered (Geertz 1973). Humanity is located in relation to the rest of earthly and spiritual creation. Often in regards to the rest of earthly creation, man is located in a position of seniority[8].

Religious beliefs are "sincerely held" (Sullivan 2005, p. 147). The belief is firm and resistant to change, either through argument or empirical contradiction[9].

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[7] The extent to which this is believed to be literally true varies in different Christian denominations. However, some belief in the divine inspiration of the words written and stories told in the Bible is common to the vast majority of Christians.

[8] Examples for this can be seen in both western and eastern religion. Man is installed as steward over Creation in Christian theology (e.g. Genesis 1:26). In Mahayana Buddhism, the Manusya (Human Realm) is located below the Asurya (Realm of the Demi-Gods) but above the Tiryagyoni (Animal Realm) in the cycle of samsara (reincarnation). In both cases humanity is positioned at the pinnacle of the earthly with only non-earthly, spiritual beings above.

[9] For Woodhouse, defining religion in reference to belief is "bound up with a scientism and empiricism which assumes that all knowledge is primarily a matter of (testable) propositional belief" (2011, p124). The criticisms levelled at religion conceptualised in this way claim that religious beliefs are founded on unreliable evidence and fail to hold up to the scrutiny of empirical testing. From the perspective of this critique, failure to alter beliefs in the light of empirical testing, or to subject belief to this kind of investigation, is characteristic of religion, and its primary failing. Religion defined in this way is criticised by the logical positivists and Popper in their comparisons between science and religion. This is also the kind of conceptualisation that 'New Atheists' such as Richard Dawkins often marshal in their criticisms of religion (e.g. Dawkins 2006).

Religious explanations are certain and definitive. Religion conceptualised in this way can be identified with dogmatism. An unyielding certainty characterises religious belief, belief which is directed toward a set of fundamental principles, ideas, symbols or stories.

Dogmatism, however, can be attached to beliefs which explicitly reject supra-human entities or explanations. The philosophy of Dialectic Materialism was treated in this way in the Soviet Union (Joravsky 1970; Graham 1972). Similarly, Dogmatism is not characteristic of all religious belief. The Church of England has been involved in a number of reinterpretations and re-readings of scripture. The ordination of female bishops within the church is one recent example. Dogmatism and religion are therefore not necessarily synonymous with one another. However, it is a kind of belief that can be identified historically and contemporaneously within religious groups. Contemporaneous examples include Young Earth Creationism (as detailed in e.g. Pennock 2001) and Wahhabi Islam (Naumkin 2005).

In focusing on the source, content and strength of a belief, a picture of religion can begin to emerge. This is particularly apparent when it is contrasted with other systems of belief. A schematic comparison between religion and other systems of belief is outlined in necessarily simplified form in Table 3. Religious belief can be described as strongly held belief in non-materialist forces, the source of explanation for which is supra-human. This can be contrasted with scientific belief which is produced by human methods and endeavour, focuses on materialistic forces and is weakly held. Weakly held beliefs in non-material forces explained by a supra-human force can be described as ecumenical beliefs (Bruce 1995). These are religious beliefs that through exposure to other religious forms become less strongly held and influential. Strongly held beliefs in human knowledge created through human processes can be equated with common sense; "what everybody knows", but is also the kind of belief present in the Soviet Union in regards to Dialectic Materialism.

Character of Belief/Belief System	Religion	Science	Common Sense & Ideology (e.g. Lyskenoism)	Ecumenicalism
Identified Source = Human/supra-human	Supra-human	Human	Human	Supra-human
Content = Materialist/non-materialist	Non-materialist	materialist	materialist	Non-materialist
Strength = Strong/weak	strong	weak	Strong	weak

Table 3

In defining religion I will make reference to dogmatically holding beliefs which provide a creation narrative and which deny the human in the construction of knowledge or understanding. Though this is by no means a comprehensive definition of religion, it captures some important aspects of the term religion, and is appropriate for describing a specific kind of religious form.

However, my definition of religion will not only refer to this specific form of religious belief. In my use of the term religion, I will reference its social or communal function. Religion is a force which unites and binds individuals in a community. It provides individuals in a group with an overarching framework or worldview which allows them to make sense of the world. Religion generates solidarity and fulfils the function of nomisation.

Religious Function: Social Product, Solidarity and Nomisation

> "Religion is first and foremost a matter of creation and maintenance of social bonds" (Woodhead 2011, p. 127)

Religious thought separates the world into two distinct realms; the everyday, profane world, and the sacred world around which particular rules must be observed and behaviours constrained in line with those rules (Durkheim 1912). The sacred is identified as essentially other from the ordinary, human profane world (Durkheim 1912). This otherness is characterised by permanence and immutability – the profane world changes and degrades, the sacred is persistent and immaculate.

What is defined as sacred and profane is not a matter of individual thought. Religion is "an eminently collective thing" (Durkheim 1912, p. 47). The sacred and profane are collectively defined, and the distinction between the two realms is collectively maintained. Those who share an understanding and act to maintain the distinction of what is sacred and what is profane are bound together within a specific group. These shared beliefs and attendant shared practises are a source of solidarity, connecting individuals within a group.

> "A religion is a unified system of beliefs and practises relative to sacred things, that is to say things set apart and forbidden- beliefs and practises which unite into one single moral community called a Church all those who adhere to them" (Durkheim 1912, p. 47)

Members of a religious group come together to enact shared ritual activity to reinforce their beliefs. Collective ritual activities inspire heightened emotional states, 'collective effervescences', which allow access to 'transcendental' experience. Transcendental experience, experience of a connection to the sacred or divine, is a product of the collective group activity but this social source is elided and instead supernatural explanations are offered.

> "He does sense that he is acted upon, but not by what. So he must construct piecemeal the notion of those powers in which he feels connected. And from this we can see how he was led to imagine them in alien forms and transfigure them through thought." (Durkheim 1912, p. 157)

Collective effervescences reinforce beliefs, reaffirm the appropriateness of practises and, in so doing, strengthen solidarity within a society. As well as uniting individuals into a unified moral community, shared beliefs and practices address the human emotional desire for the world to 'make sense'. Religion accounts for not the how but the why of happenings in the world, construing the world as regulated by some meaningful order or cosmic justice (Parsons 1944).

Berger and Luckman describe this function of religion as nomisation. Berger (2011) argues that human beings are compelled to impute order onto the world around them. A primary function of religion within society is nomisation; the production and maintenance of a shared understanding of the world which provides a sense of meaning for individuals.

The (re)production of a shared worldview is accomplished through the three part process of Externalisation, Objectification and Internalisation. Externalisation involves the projection of human understandings and orderings on to external reality. The concepts and orderings become objectified in that they gain a seeming facticity and essential otherness from their source of production (i.e. the society). Finally these now objectified orderings act back on their producers influencing their ways of thinking and understanding in a process of internalisation.

Berger and Luckmann (1991) and Berger (2011), argue that nomisation shields members of a community from 'anomic' phenomena (apparently random and unjust, meaningless experiences of the world; individual tragedy, random death). Anomic phenomena lead individuals to doubt the legitimacy of the order they have imputed to the world.

> "The anomic phenomena must not only be lived through, they must be explained" (Berger 2011, pp. 49)

Religion re-establishes this legitimacy by providing explanations for these phenomena, known as theodicies, which re-legitimise the individual world view and allow meaning to be restored;

> "For Berger, religion provides a system of meaning for making sense of the world, and for covering contingency with a canopy of sacred taken-for-grantedness" (Woodhead 2011, p. 124)

Science and Religion: Similar but (Aspirationally) Different

The term science describes a form of life characterised by skilled, expert practise made up of tacit and explicit components. The knowledge produced via this practise is negotiated and legitimised through social, political processes, though the social provenance of scientific knowledge goes unnoticed by scientists most of the time. A defining formative aspiration of the scientific community is to approach this knowledge always as provisional, to not accept a piece of scientific knowledge as definitive or closed to revision.

The term religion describes a form of life characterised by a quality of belief that imbues certain beliefs, understanding and symbols with sacred quality. This sacred quality renders beliefs and understanding certain, definitive and resistant to change. What constitutes the sacred, the content of religious belief, is socially defined, though the social-constructedness of sacred things must be elided in order to maintain their sanctity. Religious belief unites individuals into a single community and reinforces the sense of connection to one another individuals feel within a group. Membership of a religious group, and the understanding of the world this membership provides, orders experience of the universe in a meaningful way and shields individuals from meaninglessness.

For the social scientist, science and religion are both collective. The knowledge and understandings of the world they produce are a product of a particular social organisation at a particular time and place. Religious thought and understandings are not given by some supernatural power to man, they are the inevitable by-product of communal living, and their specific content is the result of the specific structure of the community in which they appear. Scientific knowledge and understanding is not produced solely through the rational method of hypothesis, observation and deduction. What counts as an acceptable hypothesis, how an observation is to be interpreted, and how this interpretation solidifies into fact is a matter of negotiation and agreement amongst individuals who inhabit a form of life with a shared natural attitude. Scientists possess a complementary skillset and expertise, shared language and congruent ideas of acceptable ways of 'going on' as scientists, which allow them to act and make sense of the world as scientists. Members of a religious community have a shared understanding of the world, of how to behave within it which orders their reality and makes their experience of it meaningful.

The knowledge and understandings of the world produced in and by scientific and religious groups are epistemically similar. Both are inherently human-made, the product of social forces. However, it is possible to differentiate science and religion[10]. Though the knowledge or understandings of the world they produce may have a similar epistemic status, this is not to say that they are alike in other ways, or are indistinguishable from one another.

Demarcating science and religion involves identifying the formative aspirations of scientific and religious social groups. A religion or a science is constituted by individuals acting in a community. These communities "define the ways in which [individuals] can legitimately intend to act as members of that group" (Collins and Evans 2017 p. 33). Groups provide a framework for individual behaviour, providing guidelines on acceptable and unacceptable ways of going on as a member of that group. Individuals may contravene these guidelines some or most of the time, but they will have an awareness that they ought to act in a particular way. This is why these guidelines are described as intentional or aspirational. They set out what *should* be rather than what always *is.* In assessing the formative aspirations of different

[10] Why it is not only possible, but preferable, to undertake this differentiating work will be discussed in the concluding chapter of the thesis. Briefly, viewing science and religion as essentially the same diminishes both endeavours and has potentially harmful consequences for the moral and democratic functioning of society.

groups, differences can be identified, and a religious and scientific form of life can be demarcated from one another.

> "There is no clear fact-value distinction only a distinction between different cultures with different formative intentions" (Collins et al. 2010, p. 188)

The Formative Aspirations of Science and Religion

Scientific and Religious communities aspire to uphold sets of values which demarcate them from each other and other forms of life. Some of these formative aspirations overlap. However, these two forms of life also have different, and occasionally conflicting, formative aspirations and can be distinguished from one another on those grounds.

Those formative aspirations which could be said to overlap are detailed in Table 4. They include the aspiration to universalism, the aspiration of disinterestedness and the aspiration of continuity of knowledge. Scientists should judge people on the quality of their science, religious people should judge others on the quality of their faith. Scientists should act to further science, not for their own gain. Religious people should act in service to their religion, even if this requires self-sacrifice, and not for personal glory, fame or wealth. When creating new knowledge, scientists should aspire to align it with pre-existing theories. For the religious, experiences should be interpreted in the light of existing scriptural wisdom.

SHARED FORMATIVE ASPIRATIONS	
SCIENCE	RELIGION
Universalism: science open to all regardless of gender, creed, sexuality. People judge on quality of their scientific practise	**Universalism:** religion is open to all (proselytising). People judged on the quality of their adherence to faith. Functional application of religion – express shared values of whole group
Disinterestedness: science done not in service of own gain or with overt political ends	**Disinterestedness:** religion practised in service of the religion/good of others/for god
Honesty and Integrity	**Honesty and Integrity**
Continuity: new knowledge produced should try and fit with that already conceived; revolution should be reluctantly undertaken	**Continuity:** new interpretations should fall in line with what has come before (Hadith, Papal Bulls) revolution should be undertaken reluctantly

TABLE 4

The forms of life are also defined by aspirations which are different but not in conflict. These are presented in Table 5. In the scientific form of life these include the aspiration to maintain the essential tension between the individual and the community, and the valuing of expertise. In the religious form of life, these include the aspiration to value the strength of individuals' faith, provide a moral or normative code by which to live, provide a sense of meaning and access to transcendental experience.

UNOPPOSED FORMATIVE ASPIRATIONS	
SCIENCE	RELIGION
Expertise: valuing the contribution of people who know what they are doing and what they are talking about – not just people who are credentialed/in authority (though it is difficult to separate the two)	**Strength of/Commitment to Faith:** valuing/respecting/exemplifying those who are committed to the beliefs of the faith, act in the right way
	Values/Moral guidance: a code which extends to all areas of life and influences and guides all behaviour
Essential Tension: individuals can find things which go against mainstream understanding, and eventually overturn it	**Meaning :** justification for existence and protection from anomic phenomena
	Transcendent experience: stimulate emotions and inculcate within individuals a feeling of connectedness to each other and something beyond; experiences of the supernatural

TABLE 5

However, there are also a number of divergences that allow me to legitimately distinguish between the two forms of life. The opposing formative aspirations are presented in Table 6.

Opposing Formative Aspirations	
Science	**Religion**
Observation: Finding things out through looking at the world	**Authority of Scripture**: Understanding world through adherence to teaching/ scripture
Corroboration: Repeated looking means more evidence/support for theory	**Anti-empiricism**: Claims are not proved or disproved/made stronger or weaker through observation/looking – faith is required
Falsification: claims should be open to being disproved. How this could occur should be set out	
Organised Scepticism: Claims must be open to criticism, and community must question new claims (doubt in spite of belief)	**Organised Faith**: Claims must be accepted, must try and resist doubt about certain tenets of belief (belief in spite of doubt)
Open-endedness: Science isn't finished or certain/definitive	**Closed**: (At least some core of) religious understandings of world are definitive/closed (dogmatism)
Generality: The wider the application of a theory/idea the better	**Total Generality**: Religious explanations apply universally

Table 6

Open vs Closed-endedness

Science aspires to a continual process of finding out new things. Scientists should never say that scientific understandings are definitive. New understandings may be generated at a later date. Though some ideas or theories are considered more likely to change than others, in principle (and aspirationally) there are no scientific theories that cannot be overturned. Conversely, an aspect of the religious form of life is investing certain principles or ideas with certainty. Though different religious practises will invest different ideas with this kind of certainty, and different religions will be more likely than others to accept revisions, an aspiration of the religious form of life is to view a set of ideas related to the religion as definitive and unchangeable.

Sources of Authority: Empiricism vs Anti-Empiricism

Science aspires to discover things about the world through observation. Though the problem of induction is intractable, the form of life of science aspires to promote theories that have been corroborated through repeated observation and which have laid out the conditions under which they could be falsified. The creation of scientific knowledge requires social processes of negotiation in order to interpret and settle the meaning of these observations, but the aspiration amongst the community is to utilise observation.

Religious forms of life aspire to resist these kinds of empirical grounds for belief. The source of what to believe, rather than coming from observation of the world, comes from the stored wisdom and teaching of the religion in the form of scripture. The world must be interpreted in light of this teaching. The teaching is invested with a sacred significance which is aspirationally different from the way in which scientific theories should be approached. An aspect of the sanctity applied to these teachings is reading them as certain and definitive (as described above) another aspect is denying their human provenance (as suggested by Durkheim). Scriptural teachings are often presented as 'the word of God' passed directly down from a supernatural being and unadulterated (or unprofaned) by human intervention.

The existence of the universe and the complexity evident within have been offered, by respectively Thomas Aquinas in his cosmological argument and William Paley in his argument from design, as observable proofs for the religious beliefs, specifically the existence of God. Rather than providing the content for belief, these arguments provide justification for accepting the content of received wisdom of the scripture (in this case the existence of God, and his role in the creation of the universe). Observation corroborates what is already believed, confirming scriptural wisdom, rather than challenging or leading to the revision of belief.

Generality vs Meaning

Scientists aim to have their explanations account for a wide range of phenomena. The more general a theory the better it is. Describing a small aspect of the world is useful, but if understanding can be generalised beyond the specific example, it is more useful. However, there are limits to the generalizability of a scientific theory. Scientific theories should not be established as *grand-recit* or meta-narrative, nor as the material for an all-encompassing world-view. As science is open-ended, its theories based in observation, falsification and social negotiation, they provide necessarily unstable foundations for a totalising cosmogony. Scientists who claim that some theory (be it evolution or relativity) can be applied universally are displaying action tokens which do not match up the overall aspirations of the scientific community.

An aspect of the religious form of life is to provide exactly these kinds of worldviews. Religious forms of life aspire to produce grand-narratives which justify existence and human experience of it. One of their functions is to render life meaningful for their adherents, and doing so requires a way of looking at the world that provides consistent explanations of the mass of phenomena experienced.

Organised Scepticism vs Organised Faith

Where science and religion most obviously differ is in the formative intention of organised scepticism. Organised scepticism suggests a group mentality of doubt towards all knowledge, a questioning of new findings and a willingness to overturn previous understandings when new knowledge is eventually accepted (even though in practise this is difficult to always maintain). Religion stresses an organised faith in (at least some core of) given understandings. The extent to which these given understandings are held to be literally true can differ, but a faith in the message they convey is deemed necessary in order to practise religion of one form or another (even when holding onto faith is difficult as e.g. during experiences of anomie or crises of faith).

In both the religious and scientific forms of life these values are aspirational. These are guidelines for behaviour that individuals within these communities aspire to – even if they cannot always (and often don't) live up to them. This is how people within these different forms of life should try to behave

Conclusions: Science and Religion Defined

Science is a collective activity of (tacitly and explicitly) expert individuals (Collins and Evans 2007). Sub-groups within the collectivity of science will have their own specific practise languages, which will create boundaries between groups within the wider community of science. However, the wider practise will be distinguished by the values that those sub-groups as an entire community aspire to uphold (Collins and Evans forthcoming).

Some of the formative aspirations of science are common to other forms of life, including the religious. However, these forms of life are constituted by contrasting aspirations. Science aspires to open-endedness, empiricism, generality and scepticism. Religion, in contrast aspires to closed-endedness, anti-empiricism, meaning and faith.

Religious belief is a sincerely held faith in received wisdom, passed from god or gods to humanity. Religious belief is often centred on a creation narrative, a narrative that describes the provenance and desired cosmic order of the universe, usually locating humanity in a position of some importance. I will characterise the quality of religious belief as belief that is resistant to change; is certain and dogmatic, and rejects or discounts alternative understandings (empirical or otherwise). It is belief which consists in supra- or non-human explanations for phenomena.

I will utilise this definition of religion when comparing the different portrayals of science in television programmes. Utilising this definition it is possible to identify if something appears as religious, if it shares similarities with the religious form. If a programme represents science as being able to provide a definitive creation narrative that is uncontested and permanent, and that locates humanity at the pinnacle of creation, I will argue that it is utilising the religious form. If a programme presents scientific knowledge as certain and unchanging, I will argue it is utilising the religious form. If a programme presents scientific knowledge as revealed through minimal human skill or intervention, as yielded to man by a compliant nature, I will argue that it is utilising the religious form.

The source of religion is the social group in which it is practised. Religious sentiment is (re)produced and maintained through collective effervescences. Religious belief in a group serves two functions. It acts to bind that group together, producing a sense of connection between individuals (solidarity) as they have a shared conception of the world (Durkheim 1912). This shared understanding provides the function of nomisation. Religion acts to provide a totalising framework or worldview for understanding the phenomena experienced in the world. The world is made meaningful through shared understanding. This is particularly relevant to those phenomena which lack immediate explanation (tragedy). Religion acts to legitimise these phenomena, it provides group members with theodicies; explanation for that which lacks logical explanation. This allows the world to remain understandable for the individual, shielding them from meaninglessness or anomie (Berger and Luckmann 1991).

I will utilise this definition when discussing both how science is presented in the religious portrayal and the function that the religious portrayal of science could serve. If science is presented as being able to provide a complete explanation of the world which provides the foundation for a worldview which allows individuals to make sense of their world and be shielded from potentially anomic phenomena, then I will argue it is being presented in a religious form which may serve a religious function.

I will suggest that those programmes which utilise the religious form in their representation of science could serve a religious function. I will assess the extent to which science television programmes can serve as shared representations around which groups can collectively effervesce, through which solidarity can be (re)produced and ordered and meaningful understandings of the world established and maintained.

CHAPTER 2
SCIENCE, PUBLIC(S) & MEDIA:
REPRESENTATION, COMMUNICATION AND UNDERSTANDING

Early interest in the relationship between the public and science identified a public which did not know enough scientific facts. Increasing the public's factual scientific knowledge, or increasing public 'scientific literacy', was the goal. Knowing more science facts made citizens better able to participate, both individually and collectively, in a modern techno-scientific democracy.

Out of this movement a focus on public attitudes towards science developed. The lack of scientific knowledge amongst the general public was thought to encourage negative attitudes towards science. Negative attitudes threatened public support for science, and its prestige in modern societies. Positive public attitudes to science were desired to increase public support, respect and enthusiasm for science.

These conceptions of the proper relationship between science and the public were challenged in the early 1990s. Building on work in science and technology studies (STS) and the sociology of science (SSK) two alternative conceptions of the relationship between science and the public were developed. The process of science, it was argued, should be communicated to the public. The public need to understand the social and cultural processes which produce scientific knowledge in order to properly assess the claims of scientists in policy debates and make informed democratic decisions on policies in which science is implicated. More radical arguments were made that scientists needed to better understand and engage with the public. The cultural hegemony of science was challenged. If science is just another cultural institution, then it has no more right to demand public understanding and support than any of the other institutions in a modern society. Privileging scientific knowledge over other forms of understanding is undemocratic.

In what follows, I will outline these differing approaches to what the public should know about science, and why that knowledge is important. Of equal importance is how publics come to receive knowledge of science. Science communication shapes understanding, attitudes and the potential for and quality of engagement. My focus will be the mass media, and particularly television.

I will suggest that though efforts to engage the public and science in mutual dialogue are important, public perception of science, how it is understood, is still shaped to a large degree by approaches which communicate science in a unidirectional fashion. By focusing on media representations of science, I will show that the way in which science is perceived is shaped by the way that it is represented in the media.

In the final section of the chapter, I will discuss the importance of exploring how media representations of science are created. If public understanding is shaped by media representation, the forces which shape media products need to be understood.

Here I try to explain:

- How the relationship between science and the public(s) has been conceptualised
    - Why the public need to understand science
    - What the public need to understand about science
- Where the public get their information about science from
    - How these different sources (specifically media, specifically television) shape public understanding of science
- How and why these media products are encoded with particular messages
    - How representations of science are produced and what forces shape the representations of science in the media

Understanding Science

Academic interest in the relationship between science and the general public can be traced back to the 1960s. There are identifiable movements within which the concerns of researchers shift. Bauer et al. (2007) describe the first two of these as the Scientific Literacy and the Public Understanding of Science (PUS) movements. The scientific literacy movement is concerned with public levels of knowledge of science. The PUS movement is interested in levels of knowledge, but also with how knowledge and attitudes towards science are related.

Science Literacy

The scientific literacy movement was built on the canonical model of science. Science literacy scholars (e.g. Miller et al. 1980) saw scientific understandings of the world as essentially correct. Due to the rational-empirical scientific method, scientists can provide reliable and useful knowledge and understanding of the world. The social and political importance of science was also stressed. Science was conceived of as one of the crowning achievements of modern western society. A normative commitment to ensuring that science was understood and valued in these terms by the citizenry of a modern western society was made.

> "The science community must redouble its efforts to present science as a fully understandable process, "justifiable to man" and controllable by him" (Morrison 1969, cited in Miller 1983, p. 32)

Communicating science to the public increases scientific literacy. Communication of science – from educators, media outlets and scientists – which increased levels of public scientific literacy was needed to create a practically and politically competent populace, (Miller et al. 1980).

> "The literacy idea attributes a knowledge deficit to an insufficiently literate public. This deficit model serves the

> education agenda, demanding increased efforts in science education at all stages of the life cycle (Bauer et al. 2007 p.80)

For the scientific literacy advocates, scientific literacy provides personal benefits to individual citizens and is vital in the proper functioning of democracy.

To successfully navigate a modern society an individual requires a basic level of scientific knowledge and understanding (Gregory and Miller 1998). An individual who knows that boiling water will kill bacteria is better equipped to deal with the kind of problems they may face if the sewage system is compromised. A Popperian understanding of the scientific method produces in individuals the right quality of mind to contribute to a modern techno-scientific society. Scientific knowledge makes individuals more practically competent in their everyday lives and more employable in a technologically sophisticated society.

> "The idea of "scientific literacy" builds on a double analogy. Science is part of the cultural stock of knowledge with which everybody ought to be familiar. Scientific education ties in with the quest for "basic literacy" in reading, writing and numeracy." (Bauer et al. 2007 p.80)

On the political level, the influence of science in society requires scientifically literate citizens to make properly informed individual and policy decisions. Scientific issues are implicated in many policy decisions. A lack of understanding of science means that the public cannot legitimately participate in science based policy debates.

> "As time goes on human events will become even more entwined in science, and science-related public issues in the future can only increase in number and in importance. Civic science literacy is a cornerstone of informed public policy" (Shen 1975, p. 49)

What counted as scientific literacy was a grasp of a broad range of scientific facts and a Popperian view of the scientific method. In the US (under the banner of National Science Foundation and headed by Jon Miller) and the UK (e.g. Durant et al. 1989) throughout the mid-1970s and into the 1980s surveys containing 'scientific knowledge quizzes' were carried out to ascertain public levels of knowledge. These included questions such as "Does the earth go round the sun or the sun round the earth?" Results from the 1980s showed that in Britain, just over a third (34%) of the sampled population were able to provide the correct answer to this question with the US fairing only slightly better (46%) (Durant et al. 1989).

For science literacy advocates, these results showed that the public were insufficiently scientifically literate (Miller et al. 1980). This lack of understanding compromised individual ability to function in the modern world. A public without the required level of scientific knowledge were also unable to properly participate in democracy, legitimising technocratic authority (Bauer et al. 2007).

Public Understanding of Science (PUS)

In the mid-1980s the focus of research shifted away from a concern with scientific literacy. This shift in focus in the UK context was influenced by the publication of the Bodmer report (1985) which identified a deficit amongst the public of positive attitudes towards science. Research which revealed low levels of scientific literacy (US, British: Durant et al. (1989), European: Bauer at al. 1994) also indicated that individuals with low levels of scientific literacy tended to hold negative attitudes towards science (Durant et al. 1989). Individuals with more scientific knowledge were identified as more favourable towards science, to be willing to support it politically and financially and to adhere to the advice of scientists (Durant et al. 1989; Bauer et al. 1994). The widespread deficit in knowledge was assumed to indicate a widespread deficit in positive attitudes.

> "The concern for scientific literacy carried over into PUS. A knowledge measure is needed to test the expectation "the more you know, the more you love it." However, the emphasis shifts from a threshold measure to that of a continuum: not "one is either literate or not," but "one is more or less knowledgeable." The correlation between knowledge and attitudes becomes the focus of research" (Bauer et al. 2007, p. 83)

Social institutions with a stake in continued public support for science attempted to combat the prevalence of negative views of science, adopting either a rationalist or realist approach. The rationalist approach assumed that negative attitudes could be eradicated with more knowledge of science. The Committee on the Public Understanding of Science (CoPUS), a joint venture between the Royal Society, Royal Institution and the British Association for the Advancement of Science adopted this approach, attempting to increase positive public attitudes towards science by increasing public scientific literacy.

Despite the initiatives of CoPUS, the upswing in public support for science did not materialise in the predicted way. The extent to which higher scientific literacy and more positive attitudes are related proved difficult to illustrate.

> "While the [rationalist] PUS paradigm was fixated on the common sense axiom "the more you know, the more you love it," empirical investigations of the knowledge/attitude relationship have remained inconclusive until recently" (Bauer et al. 2007, p. 84) [My Brackets]

What more recent research showed is that rather than producing positive attitudes, knowledge is related to the strength with which an attitude is held (Allum et al. 2008). Individuals with more knowledge will hold stronger attitudes, which are harder to change, whether they are positive or negative (Bauer 2009). High levels of knowledge of science can produce either positive or negative attitudes towards science. Contentious or controversial scientific issues are more likely to be viewed negatively by individuals with high levels of knowledge (Evans and Durant 1995). Familiarity can breed contempt (Miller 2001). Attempts to increase public support for science through increasing public science literacy showed only limited success (Gregory and Miller 2000).

The realist approach saw attitudes as linked to emotions. Increasing positive public attitudes required communicating science in ways which stimulated emotional responses. This approach borrowed its conception of the public from advertising and public relations. The public was viewed as "the consumer who is to be seduced" (Bauer 2009, p. 5). The Office for Science and Technology and Wellcome Trust (Office of Science & Technology and Wellcome Trust 2000) identified six different attitudinal clusters in the British public which varied in their levels of support for science; 'confident believers', 'technophiles', 'supporters', 'concerned', 'not sure' and 'not for me'. The first three groups were all broadly supportive of science, but their confidence in the political and regulatory system varied. The concerned group were also broadly positive towards science, but were most sceptical about the regulatory framework which surrounded it and society's ability to cope with scientific change. The latter two clusters had less positive attitudes or were less interested in science.

These different groups were to be targeted with specific marketing strategies to increase or maintain their support for science. The four groups that were supportive of science were likely to receive information about science from a wider variety of media sources, but tended to be most trusting of television documentaries and current affairs programmes. Those groups that were unsupportive of science viewed less documentaries and news programmes. Other demographic factors influenced attitudes with the unsupportive groups being populated by older and lower class individuals. Including scientific content in different formats in different communicative media was suggested as a way to reach these different attitudinal groups, reflecting their demographic make-up and media usage preferences (Office of Science & Technology and Wellcome Trust 2000).

Both the rationalist and realist PUS movements aimed to foster positive public attitudes towards science. Positive attitudes mean greater public respect for the institution of science, a benefit to those established scientific institutions. From the PUS perspective, the proper functioning of democratic society required a populace with the 'right' attitude towards science (i.e. respectful and deferential) who exhibited continuing support for science.

Both the Scientific Literacy and PUS movements assume a public deficit. In the case of science literacy this is a deficit of knowledge of scientific facts and method. The PUS movement argues that the deficit in positive attitudes towards science is more problematic for the institutions of science. For the science literacy movement a public that has a command of a body of scientific facts and a Popperian conception of the scientific method understands science, which produces a better functioning society. For the rationalist Public Understanding of Science (PUS) movement greater understanding (in terms of greater command of scientific knowledge) means more positive attitudes. For the realist PUS movement, positive attitudes can be maintained or increased by targeting different attitudinal groups with specific messages in specific formats through media likely to be engaged with by these different groups. In either case, more positive attitudes mean more support and respect for science.

The science literacy and PUS movement assume a canonical model of science, and locate science as a defining and fundamental modern institution. For these movements, science is fundamentally correct in its understandings of the world. The scientific method produces empirically founded, rationally justified knowledge of the world, scientific facts. When enough of these facts are known and the (rational, asocial) method by which they were produced is widely understood, then democracy will function properly. Scientific knowledge is the product of scientific institutions, which require public support. Negative attitudes undermine this support, threaten the privileged position of science in modern societies and in so doing undermine the integrity of democratic societies by failing to prevent irrationality. Positive attitudes towards science are required in order to protect and preserve science's status and democracy itself.

This model of science has been criticised from the perspective of sociology of scientific knowledge (SSK) and later science and technology studies (STS). These critiques were influential, in the early 1990s, in the creation of two different approaches to science communication. The Public Understanding of the Process of Science (PUPS) movement argued that the public need to understand that scientific knowledge is the product of the social and cultural organisation of particular scientific communities. The Public Engagement with Science and Technology (PEST) approach identified a deficit in scientific institutions understanding of and willingness to interact with the public, not a deficit in public understanding of or appreciation for science.

Public Understanding of the Process of Science (PUPS)

The Public Understanding of the Process of Science (PUPS) movement recognised similar problems to the science literacy and PUS movement in negative public perceptions of science. These negative perceptions, rather than being attributed to a lack of knowledge, were seen as the result of a tendency for science to represent itself, or be represented as, perfect and infallible as under the canonical model (Collins and Pinch 1998). This, it was argued, led many people to reject science when it failed to live up to these unrealistic standards of perfection.

The inaccuracy of the canonical model can become obvious when the public are asked to make a science-based policy decision. Often when asked to make these decisions, the public are not presented with a set of clear scientific facts. The scientific community can be actively involved in the process of establishing the facts, so there are no facts that can be learned which will help in the making of an informed decision. Seemingly established facts can be debated or their veracity or relevance denied in the policy arena. In these situations, understanding the processes by which scientists go about establishing facts would help the public decide who to trust (Collins and Pinch 1998). More realistic communication of science, which depicted this process in detail, was required.

The PUPS approach (and the PEST approach discussed in the next section) drew on STS and SSK research that argued that scientific knowledge is a cultural product (Collins 1992; Bloor 1991; Latour and Woolgar 1986). Scientific knowledge shares similarities with other forms of human knowledge and is not radically different or superior. Controversy plays a fundamental role in science. New scientific knowledge crystallises out of debates around empirical data which are only settled in reference to factors outside of the data themselves (Collins 1992). Scientific facts are produced through negotiation.

When involved in negotiation, scientists must assess which of the claims of their colleagues and rivals to trust (Yearley 2000a). A number of factors will influence whose claims are trusted. The institution a researcher is based at, their previous track record as an experimenter and their publication record will all influence the judgment fellow scientists make of their work. These judgements are instrumental in the creation of new scientific knowledge.

> "Trust and judgement are vital ingredients of scientific life and their presence is important to the public's response to scientific expertise" (Yearley 2000, p. 155)

As this quote suggests, the PUPS movement argued that the public need to understand that controversy, interpretation, trust and judgement are what characterise science.

The PUPS approach identified the flaws in communicating the canonical model of science, and the erroneous impression of scientific infallibility which came with it. In so doing, its aims were not anti-science. Collins and Pinch (1998) argue that scientists need to be shown as they really are; experts, not immaculate truth making machines. Scientific expertise is like other forms of expertise, it is useful and relevant in certain situations, but not perfect. Expertise is a substantive thing that individuals gain via long immersion in expert communities. Scientists do possess knowledge and understanding of the world. Scientific experts representing their communities can offer expert opinion on issues to which their expertise is relevant. However, they should not be expected to offer certainty. Expectations of certainty, when it is not provided, can lead to disappointment and rejection. This rejection of science needs to be avoided. Scientist's expert contributions should not be discounted entirely if their previous advice proved less definitive than expected.

> "Scientists are neither Gods nor charlatans; they are experts, like every other expert on the political stage (Collins and Pinch 1998, p. 143)

For a techno-scientific democracy to properly function, science and scientists need to be understood by the public in this way (Collins and Pinch 1998). The public need to understand how controversy is settled and scientific facts become stabilised. An awareness of the role of expertise in these processes and the status of expert contribution in wider debates is required. Understanding the process of science will mean that the public do not expect scientific certainty and as a result will not reject science when it fails to provide it.

> "For citizens who want to take part in the democratic process of a technological society, all the science they need to know about is controversial" (Collins and Pinch 1998, p. 3)

Understanding science in this way means assessing science in public is a matter of weighing the advice of competing expert claims. This is a skill that democratic citizens possess. Citizens rely on their own expertise, experience and discernment when deciding which politician to vote for, which plumber to employ, which airline to fly with. They assess the track record, conflicts of interest, institutional affiliation of these individuals or professional bodies and make a decision on who to trust based on these criteria. This is the same criteria which scientists employ when assessing one another's claims and should be employed by the public when weighing competing expert claims in public. This argument is made by Yearley (2000b) and summarised by Sturgis and Allum (2004);

> "Claims to expert knowledge are always contestable, depending on what one knows of the relevant institutions… all things being equal, some form of "institutional knowledge" will serve to contextualize "factual" scientific knowledge and knowledge of scientific methods when people evaluate the science under consideration." (Sturgis and Allum 2004, p. 58)

Promoting an understanding of science envisaged by the PUPS movement means that citizens are encouraged to utilise the kind of discernment which they already possess when faced with democratic decisions in which science is implicated. It counteracts the tendency of science to be understood as certain, and the negative perceptions of science, when it is shown not to be, that arise.

Public Engagement with Science and Technology (PEST)

A separate line of argument developed in the 1990s which stressed the need for science to better understand and appreciate the public. STS and SSK had shown that science was a cultural institution similar to any other. Science literacy quizzes measure a very specific kind of knowledge that does not indicate or relate to understanding of science as a cultural activity. High-profile failures of science (e.g. the environmental consequences of DDT as identified in Silent Spring (Carson 1962), the industrial disasters at Three Mile Island in 1979 and Bhopal in 1984) showed that science was subject to mistake, miscalculation and failure. Later research into the aftermath of the Chernobyl disaster (Wynne 1992), and the handling of the BSE controversy (Jasanoff 1997) revealed the problematic consequences resulting from an assumption of the inherent superiority of scientific understanding. The attitude of scientists to public concerns and contributions during these periods of uncertainty had been disdainful. Lay individuals' legitimate contributions were ignored during these controversies, closing off access to potential solutions. Publics may therefore have legitimate grounds for holding negative attitudes towards science. The epistemic and normative assumptions of scientific literacy and PUS, that science produces unproblematic knowledge of the world and citizens of a modern society should possess articulatable factual knowledge of or positive attitudes towards science, were questioned. Communication between science and the public should involve more than tackling perceived public deficits in literacy and attitudes (Gregory and Miller 2000, Miller 2001).

The Public Engagement with Science and Technology (PEST) model does not conceive of the citizenry of a modern society as a homogeneous mass which is ignorant of science. Discrete publics whose understanding of, interest in, engagement with or rejection of science will depend on contextual factors are envisaged by the PEST movement. Lay individuals possess a contextual understanding of science which allows them to draw on specific pieces of scientific understanding when they become relevant to their daily lives (Layton 1993). Science knowledge quizzes do not reveal the complexity with which public actors relate to science. Knowledge of science does not impact individual's decision making, or more general attitudes to science, in linear ways. This relationship is shaped by individual life experience and other forms of knowledge.

Attempts to produce positive attitudes to science within the public were also seen as problematic and criticised on practical and political grounds (Bauer 2009). Positive public attitudes for the PUS movement equated to respect for and deference to science. Attempts to produce a public deferential to science reflected a lack of trust in the public on the part of scientific institutions and policy makers. A public that did not understand science in favourable terms or exhibit support for science could not be trusted to come to the 'right' conclusions when science was implicated in public policy debates (the right conclusions being those proposed by or favourable towards scientific institutions) (Bauer et al. 2007).

This lack of trust in the public means their contributions to science-policy debates are unwelcome unless they align with mainstream scientific contributions. Excluding dissenting public opinions from science-policy debates reveals the hegemonic tendency of science. As scientific knowledge is a form of cultural knowledge like any other, the authority possessed by scientific actors to exclude non-scientific contributions is political, not epistemic. Scientific institutions use their political authority to frame issues as being solely the concern of science. Differing public perspectives are deemed irrelevant.

The political aims of science can hinder the production of potential solutions to science-policy debates as members of publics possess expertise gained through experiences in their own specialist fields (Wynne 1992; Irwin and Wynne 1996). These other forms of knowledge or expertise can provide legitimate and useful answers to questions that scientific institutions would have asked only of science (Irwin 1995; Irwin and Wynne 1996). Including more varied forms of expertise in debates could help to provide better solutions. Therefore, the PEST approach argues that 'lay experts' should be included in science-policy debates if their expertise is relevant, regardless of their attitude towards science. As importantly, whether 'better' practical solutions are produced or not, reframing debates or issues in accordance with non-scientific conceptions undermines the political hegemony of science. Giving voice to lay perspectives is not only of practical benefit, it is more democratic, as it challenges the (unjustified) authority of science.

The PEST approach aims to ensure that all relevant contributions, scientific and non-scientific, are given equal voice in a debate. Public framings of issues are as legitimate as scientific framings, and these different framings of issues should be weighed and assessed openly in public (Jasanoff 2005). Publics and scientists should be bought closer together, in forums which respect the relevant contribution of scientific and non-scientific stakeholders. This approach promotes upstream engagement, where publics' involvement is encouraged at early stages of scientific research and development. Publics are encouraged to play a more active role in setting the scientific agenda, and to engage in dialogue with scientists through citizens' juries, public forums and debates. Due to these diverse contributions the outcomes of science-policy debates may be of greater practical utility and are democratically legitimised. Table 7 provides a summary of the different conceptions of the relationship between science and the public described in detail in the above sections.

	SCIENCE LITERACY DEFICIT MODEL	PUS DEFICIT MODEL	PUPS DEFICIT MODEL	PEST DEFICIT MODEL
Deficit **in**	Public	Public	Publics + (Most) Scientists	Scientists + Policy Makers
Deficit **of**	Scientific Facts/ Knowledge	Scientific facts/knowledge + Positive Public Attitude toward science	Understanding of process of science (as understood by social studies of science)	Appreciation for/engageme nt with 'lay expertise'
Problem to be solved	Inability to engage in democracy	Popular distrust/ opposition	Misunderstanding of controversial science	Social irresponsibilit y of science/public rejection of science

TABLE 7

From Understanding to Communicating

Policy makers and scientists increasingly accept there is an onus on them to engage in dialogue more often and more productively with the public. Evidence for this can be seen in initiatives such as the "GM Nation?" debate in the UK (Rowe et al. 2005). However, this kind of active engagement between science and the public has potential limitations.

The resources required to hold such large scale public consultation may render them unpopular in the eyes of potential sponsors (e.g. national governments as argued by Rowe et al. 2005). When they are initiated, efforts at public engagement have been criticised for failing to genuinely engage (Wynne 2007). Non-scientific re-framings of issues can be ignored in these events, their legitimacy questioned by representatives of science on the grounds that they are non-scientific, undermining the stated aims of science-public dialogues. If publics' contributions are taken seriously, the policy impacts of the conclusions and recommendations of science-public engagement activities can be limited (Rowe et al. 2005). Bauer et al. (2007) have suggested that engagement events can recreate the same kinds of hierarchies and power relations between science and the public that they are designed to dissolve. Criticism of the specific publics included in the debates can be used to discount their perspectives. Alternatively, engagement activities can be used as forums to persuade the public of the scientific perspective and continued or re-instigated until the public accept the scientific frame.

Members of the public must also invest their time and effort for engagement activities to be successful. A public who are willing and able to participate is required. This can lead to problems of representativeness, as individuals who already have some vested interest in the issue under debate may be more likely to participate. This problem was identified during the "GM Nation?" debate. Though roughly twenty thousand individuals were engaged in some way during the debate, they were found to be unrepresentative of the wider UK population, in that they tended to be less positive towards GM food than the average member of the UK public (Rowe et al. 2005).

Neither scientists nor publics enter into engagement interactions free from pre-conceptions. Scientists are influenced by their own understandings of science, the public and the best way for the two to interact when interacting with the public. Many scientists' understandings of science do not take into account, or actively reject, sociological contributions to the understanding of how science works[11]. In order to successfully practise science, most scientists need to actively disregard the findings of sociological research (Collins and Evans 2017). Publics engage with science holding pre-conceived understandings of and attitudes towards particular issues which are the focus of engagement, science more generally and the proper relationship between science and the public.

Communicating Science

Science and the public come into contact outside of PEST style engagements frequently and in much less deliberative and egalitarian contexts. Unidirectional mass media communication is a ubiquitous and influential context in which science and the public are brought into contact. How science is represented in mass media influences public perceptions. These perceptions subsequently shape how people come to engage with science. If science is represented and perceived as a font of certain, definitive knowledge then publics will be much less likely to engage with it critically and sceptically (Dhingra 2003). If science is considered an imperialistic, hegemonic force intent on maintaining its position of power through marginalising opposing voices, then it can be resisted on political grounds (Wynne 2000, 2001; Jasanoff 2004). If science is shown to be and viewed as a skilled and expert, yet provisional and communal enterprise, its relevance to specific technical issues can be recognised whilst a healthy scepticism towards any totalising tendency can be maintained (Collins and Evans 2007; Collins et al. 2010)

The Mass Media

Post-education, members of the public are most often exposed to science through mass media (Koolstra et al. (2006); Schäfer (2012)). The extent to which media representations directly impact audience perceptions, understandings or attitudes has been subject to long debate in media and

[11] Evidence for this can be seen in the 'science wars' of the mid 1990's (Ross 1996; Labinger and Collins 2001)

cultural studies (see Kitzinger 2004; McQuail 2005 for thorough histories of this debate). Alongside broader concerns relating to perceptions of women, ethnic minorities or various professions, public perceptions of science are implicated in this debate around media effects. Two broad schools have arisen in this debate, built around either a transmission or reception model of media.

The transmission model sees media messages as being transmitted into passive audiences where they are received much as their producers intend. The reception model suggests audiences play a much more active role in the interpretation of media messages. Media messages are seen as polysemic, or open to multiple interpretations. Demographic factors impact the way in which media messages are interpreted by individuals. Extreme examples of this position deny the producer any impact on how their media content is interpreted. The positon is summed up by Barthes' suggestion that "the author is dead" (Barthes 2001).

I will adopt a position between the furthest extremes of each tradition. I will accept that media messages have identifiable impacts on the understandings and attitudes of their audiences whilst acknowledging these messages can be interpreted in multiple ways. The way science is portrayed on television affects how it is understood by the public. An interest in these portrayals is therefore justified.

> "The mass media are rarely our sole source of information and we actively interpret and consume the media for our own purposes and pleasures. The paradox is that in spite and sometimes even because of such audience engagement, the media can have a very powerful role in defining, maintaining and even transforming the way we see the world" (Kitzinger 2004, p. 31)

The focus of my analysis will be non-fiction, documentary television representations of science. Television is one of most ubiquitous and trusted medium for the communication of science (Koolstra et al. 2006). The documentary genre is perceived as providing more true-to-life representations of topics than other genres (Corner 1996). Television documentaries are a trusted genre in a trusted medium (Office of Science & Technology and Wellcome Trust 2000). Documentary representations of science are likely to be viewed as accurate and broadly faithful. Therefore, television science documentaries will play an important role in shaping public perceptions of science.

Transmission Models

Framing theory and Cultivation theory are based around a transmission model of media. Their analysis of how media representations impact public perceptions differ in terms of scale, framing being concerned with how specific representations impact perception, cultivation theory taking a wider view of the entire media landscape. Taken together it can be argued that the presence of particular frames in the media can cultivate particular perceptions. Similarly, the absence of certain frames can render particular perceptions illegitimate or entirely absent.

Framing

Framing theory outlines the different discursive and rhetorical tactics used in presenting an issue in the media. Media frames legitimatise certain ways of talking and thinking about issues, and delegitimise others. What is excluded from a frame is as important as what is included within it.

> "Frames are defined in this body of research as organising central ideas on an issue. They endow certain dimensions of a complex topic with greater apparent relevance than the same dimensions might appear to have under an alternative frame…Frames are said to be used by audiences as "interpretative schema" to make sense of an issue: but they are also employed by journalists to condense complex events into interesting and appealing news reports…frames help to

> simplify complex issues by lending greater weight to certain considerations and arguments over others" (Nisbet 2009, p. 45)

The way an issue is framed, what is included and excluded in the presentation of an issue, will affect the way an audience interprets it. The way in which a scientific issue, or science more broadly, is framed in the media affects how it is understood by the public.

Framing devices can draw on pre-established cultural tropes to render an issue more familiar or understandable. However, these tropes bring with them particular interpretive baggage, rendering some interpretations more legitimate (and likely) than others. Following the cloning of Dolly the sheep, Holliman (2004) found that the media framed the story with references to science-fiction, Frankenstein and ethical issues around human cloning and the risk of playing god. This had a clear impact on the way in which focus group members discussed broader issues around cloning. Focus group members drew heavily on these metaphors and focused on these aspects of the cloning process. Discussion was shaped by the media frames which focus group members had been exposed to. These frames provided not only discursive material but legitimation to particular ways of talking (and thinking) about the scientific issue of cloning.

Rather than the use of specific metaphors, the framing of an issue as a debate between two equally well supported points of view can lead to interpretation of the issues as undecided or controversial. This framing is often identified in media coverage of climate change (e.g. Nisbet 2009; Spence & Pidgeon 2010). The public response to the MMR controversy was similarly shaped by its framing as a balanced debate (Boyce 2006). The claims of the pro-MMR camp, which represented the scientific consensus view, were presented alongside the claims of anti-MMR groups, who were formed mostly of concerned parents, politicians and celebrities. This presentation alongside one another, in newspapers, radio and television, gave the competing claims the appearance of epistemic and evidential equivalence. Through reception analysis, Boyce showed that over time, this led to the perception that the basis for the anti-MMR campaign, claims made by Dr. Andrew Wakefield of a link between MMR and autism, had much greater support within the scientific community than was actually the case. Publics often assumed that this debate was equally balanced within the scientific community, and were shocked to find this wasn't the case[12].

Framing can also occur on the level of individual instances of media content (e.g. specific television programmes). The way in which specific linguistic and visual devices are utilised will lead to differing interpretations. Dhingra (2003) investigated the way in which teenage school children's perceptions of certainty surrounding science were affected by different presentational formats, which used differing language framings in their discussion of science. A comparison was drawn between a presentation of science as a set of simple and definitive facts and a representation of science as more uncertain and requiring interpretation.

> ""A noteworthy finding of this study concerns the voice of the program, whether science is presented as a set of facts with a high degree of certainty or whether it is presented as process with a certain amount of uncertainty involved in the interpretation of results. In the former case (represented in our study in the documentary and magazine formats) most

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[12] Boyce quotes the following exchange from a focus group to illustrate the surprise many participants expressed on hearing the lack of support and evidence for Wakefield's claims.

> "M29: And his research was based on two thousand people or not even that?
> TB: Twelve.
> M2: Twelve—a lot less.
> V2: I'm gob-smacked that based on that research we are in this situation! I am really gob-smacked!
> TB: You're all looking at me with quizzical eyes. I need to say this for the tape. (laughter)
> M1: I'm reeling a bit.
> TB: Why are you reeling?
> M1: Because of the number. I'm quite shocked that's all on such small numbers. I am. I am shocked.
> TB: Just shocked or anything else?
> M1: Well I would say I feel a little bit stupid really, I feel I've been completely washed along with the crowd" (Boyce 2006, p. 901)

> students had no questions after viewing. In contrast, in the latter case (found in the news and drama genres in this study) students were involved in solving the problems presented and had both questions and comments after viewing the segment." (Dhingra 2003, p. 251)

When science is presented in certain terms its audience accepts it as certain. This kind of representation engenders an unquestioning response. Presentations which show science to be uncertain and subject to interpretation invite discussion and debate.

Frames can draw on pre-established metaphor, present issues as being controversial or settled and utilise linguistic and visual devices to render an issue more certain or uncertain. These different framing devices will tend to produce differing interpretive responses in audiences.

Cultivation Theory

Cultivation theory takes a broader view of the media landscape. It suggests that audience member's worldviews are shaped by the totality of the media content they are presented with. Those issues, topics, groups that preoccupy the media will also preoccupy the worldviews of those individuals who consume high levels of media output. More recently, given the now diverse media landscape, researchers have begun to assess the way in which specific genres or even programmes (Podlas 2006) can cultivate particular understandings within their audiences

Cultivation theory was developed by George Gerbner (et al. 1981; 1986), who argued that over time particular impressions of the world are created in audiences through their exposure to media. Individuals who are exposed to greater quantities of media output will construct their impressions of the world in line with the representations they are exposed to. Those things which are focused on and repeatedly represented in the media come to take on greater significance to the individual who consumes large amounts of media output. For instance, the news media often focuses on violent events (Gerbner et al. 1986). Dramatic characters are more likely to be victims or perpetrators of violence than real life individuals. Gerbner et al. (1986) showed that individuals who consumed large amounts of media tended to overestimate the amount of violence in the world.

The corollary of this idea is symbolic annihilation (Tuchman 1979). If the media does not represent an issue or group, then that issue or group is rendered insignificant or invisible in the worldview of the individual who consumes large amounts of media. Symbolic annihilation is the process by which certain people, social groups, professions or issues come to matter less to audiences whose worldviews are shaped by the high levels of media they are exposed to. Evidence for media cultivation and symbolic annihilation has been identified in reference to science programmes, the so called CSI effect being a particularly useful illustration.

The "CSI effect" describes an idea that US jurors who were heavy viewers of the fictional forensic science television programme CSI (or its derivatives) were unduly influenced by the presence (or lack thereof) of forensic evidence in court cases (Cole & Dioso-Villa 2009; Podlas 2006). CSI is a popular fictional crime show which details the exploits of a group of criminal investigators who utilise forensic techniques to solve crimes. Within the programme, Tait describes the forensic science as being presented in the following way:

> "The fictioned science of CSI figures a compelling universe where crime is dealt with hygienically by teams of elite scientists who bring truth to light with superhuman haste. It presents a bounded and teleological world, where truth lies at the end of a microscope and from an infinite range of possibilities the correct evidence is always collected and accurately read." (Tait 2006, p. 59)

Various studies have investigated the extent to which the CSI effect is actually identifiable and whether it impacts juror's ability to come to a verdict

(Keuneke et al. 2010; Holmgren and Fordham 2011; Ley et al. 2012). The original contention was that jurors expected forensic evidence to appear frequently in trials and be robust, certain and decisive when it was presented. In court cases when this did not occur, it was suggested that jurors would be less inclined to provide a verdict. However, there is limited evidence that jurors whose expectations were not met were unable to come to a verdict when they were not presented with decisive forensic evidence (Holmgren and Fordham 2011).

These studies, however, show how repeated media representations cultivate a particular understanding of (in this case forensic) science in audiences. Individuals who watched CSI had different expectations of the court room procedure, and the science used within it, than those who did not. Kim et al. (2009) and Schweitzer and Saks (2007) found that viewers expected more forensic evidence to be presented in court. Schweitzer and Saks (2007) also found that CSI viewers considered themselves to have higher levels of knowledge about forensic science than non-viewers. Brewer and Ley (2010) found a similar relationship between CSI viewing and perceived knowledge of forensic science. They also found that viewers supported the establishment of a national DNA databank for criminals, expected DNA evidence to be utilised more decisively in court and believed forensic science to be more robust and decisive than non-viewers.

Though there is some debate as to the specific character of the CSI effect, and the extent to which it impacts on jurors abilities to properly carry out their role, there seems to be a clearly identifiable difference in perceptions of forensic science between those who are heavy viewers of CSI (or similar programmes) and light or non-viewers. The perception of forensic science as robust and decisive aligns with CSI's representation of science as described by Tait (2006). Repeated exposure to the CSI representation of science has cultivated in its audience a vision of science as a flawless arbiter of truth.

The notion of symbolic annihilation justifies the suggestion that a lack or absence of perceived alternatives to this sanitised and certain science further reinforces the view of science as certain. A lack of public understanding of the process of science can be attributed to a systematic lack of this kind of representation of science in the media. Failing to represent the cultural and social aspects inherent to the creation of scientific knowledge leads to a resulting lack of cultivation of this kind of understanding of science. If the logic of cultivation theory is accepted then an identified absence of understanding in the public can be attributed to a lack of representation in the media.

Reception Models

Running counter to top down models of media influence are those which emphasise the audience's interpretive power when consuming media products. Framing and cultivation theory assume a straightforward model of audiences interpreting media content in line with the way it is framed or, through cultivation, over a period of time having their understanding shaped by the (absence of or repeated) representations they are exposed to. Reception models argue that audiences interpret media output in (sometimes unpredictable) ways which do not necessarily align with the dominant frames present in the media they are exposed to.

Hall suggests that media texts are 'polysemic' (Fiske 1986; Hall et al. 2004); they are open to a variety of interpretations. Media texts are encoded during their production with a specific set of meanings, but once produced audiences can (and are likely to) decode these texts in a variety of ways, resulting in media texts providing a different set of meanings for different audiences. Various contextual factors will impact on how an audience decodes a text. Audiences bring with them various life experiences, cultural resources, and discursive framings to their interpretation.

> "People are not blank slates who approach a film without any pre-existing identity, experience or resources. They come to the cinema (or TV set) with sets of prior opinions, views and ideas of themselves" (Kitzinger 2004, p.20)

Hall identifies three likely positions which audiences might adopt when decoding media products; the dominant, the negotiated and the oppositional. The dominant decoding accepts the framing encoded by producers. The negotiated accepts this framing in the abstract, but challenges its application in specific (local) contexts. The oppositional decoding rejects the broader framing of the issue, challenging the cultural hegemony represented in the encoded position (Kitzinger 2004). Which of these decoding occurs in practise depends on the specific issue and the specific characteristics of the audience. Exploring the audience is therefore legitimised. Understanding the "identities, experiences and resources" an audience bring to the reading of a text can illuminate why it is decoded in a particular way (Fiske 1986). Thus a focus of much audience engagement research is how audiences in practise decode a variety of media texts.

Whilst arguing that media texts can be decoded in various ways, Hall maintained that these texts are encoded during their production with 'preferred meanings'. Media texts are designed to be understood in particular ways, to carry particular messages and affect their audiences in prescribed ways. Though audiences may not always decode the preferred meaning, they will do some (or more) of the time. Some reception model scholars recognise that the producers of media content, in encoding their texts with preferred meanings, wield an influence that limits the interpretive power of the audience:

> "The power of viewers to reinterpret meanings is hardly equivalent to the discursive power of centralised media institutions to construct the texts which the viewer then interprets; to imagine otherwise is simply foolish" (Morley 1996 cited in Kitzinger 2004, p. 27)

Identifying the preferred meanings or framings of an issue can show how audiences are likely to understand an issue. How and why these particular meanings are encoded within the media products is not visible from this analysis. To understand this, an understanding of the world of media production is required.

Understanding Science Communicators: Shifting the Gaze from Products to Producers

Production is a fundamental part of the process of meaning creation in media. The processes of production vary across media. Television production involves specific processes and procedures, specific requirements that have to be met, which lead to television programmes being shaped in particular ways (Millerson 1999). These processes also vary across genre, with documentary being subject to different demands from drama, current affairs or comedy (Tunstall 1993).The television production process needs to be understood to explain how and why a television programme (i.e. a media text) is encoded with meaning. The specific demands of the documentary genre must also be taken into account when analysing documentary representations of science.

Making a television programme involves a complex process. There are a series of production phases that have to be completed before the programme is broadcast; development, pre-production, filming, post-production and editing. Research has been carried out into these specific phases of this process, or into the process as a whole. Zoellner (2009) focused on the work that takes place in developing ideas for television programmes, whilst Silverstone (1985)) and Dornfeld (1998) have followed the entire production arc of individual programmes. This research has shown that at each stage of production different people, with different aims, motivations and priorities are involved to different degrees. Individual television programme makers are also influenced by a similar set of factors to their audiences; values, preconceptions, (mis)understandings and stereotypes. Though individuals do wield a creative influence in all these stages, their creativity is limited by institutional, professional, media specific and genre constraints. The way television makers negotiate these constraints impacts on the final appearance of a television programme.

> "From the variety of social interactions that occur in its making, guided through all production stages by interpretative and evaluative acts, constrained and steered by the field of production within which the work is embedded, and articulated and interpreted through conventional codes.... Television production is a form of cultural mediation based on negotiations between powerful social agents that shape a text." (Dornfeld 1998, p. 19)

The role of the researcher is therefore to uncover the explicit and tacit rules, values, trends and fashions within the community of television producers which affect what appears on the screen. Some presentational styles, motifs or tropes observed in television programmes may be the result of temporary fashions. Others may be identified as permanent features based on the professional values and constraints of the community. To know why one representation was used instead of another an understanding of the ostensible and underlying motivations and constraints which characterise the form of life of television producers is necessary.

Conclusions

To function effectively and democratically the public of a modern techno-scientific society needs to understand science. In order for the most productive engagement between the public and science, the public need to possess an understanding of the social and cultural processes of science. Understood in this way, science will not be expected to provide certainty, and will be less likely to be rejected by the public when certainty is not provided. The public will be able to properly judge the claims of scientific and non-scientific experts in public debates about science and science based policy.

It is clear that the media has an impact on how the public understands science. The way individuals are legitimately able to talk and think about an issue is impacted by how it is framed in the media. Repeated representations will reinforce particular perceptions. The absence of competing representations will engender a concurrent absence of perception. Representations that show science as certain engender unquestioning responses. Representations that reveal the uncertainty and interpretive work that goes into science provoke more engaged, deliberative responses.

Identifying how science is represented in the media can indicate the ways science is likely to be understood by the public. Though media representations are open to interpretation, they are inscribed with 'preferred meanings' which channel the audience down particular interpretive pathways. Identifying particular representations can allow us to theorise how publics may understand science if they are exposed to them. Some representations will produce an understanding that is conducive to productive engagement between the public and science. Others will not.

Understanding the processes by which these differing representations of science are created is also important. Understanding how cultural producers understand science, their goals in producing science based media content and the various institutional, professional, genre and aesthetic constraints they face can help to explain why particular representations appear. Understanding these processes is also vital if recommendations are to be made. If some representations of science are preferable to others as they are more likely to aid engagement between the public and science, then understanding how and why these representations are produced, and how and if they can be reproduced in the future is important. If some representations are likely to produce an understanding that is counter-productive to this project, then their provenance and likely re-emergence must similarly be understood.

In the above I have intended to provide the necessary context and justification for pursuing the aims of this project. In what follows I will explain:

- The process of science documentary production

- The institutional, professional and genre constraints science documentary makers are subject to and how this shapes the model of science documentary makers adopt and communicate
- How this model and these constraints lead to the production of particular representations of science, which I describe as either secular or religious
- What characterises the secular and religious portrayals of science
- The potential social function of the religious representation of science for a subset of its audience; as a producer of solidarity and nomisation
- The problem with science being understood as a religion, and how this can be avoided

CHAPTER 3
METHODS

To gain an insight into how the public understands science the ways in which science is represented in the media need to be analysed. To understand non-fiction television representations of science – why particular representations appear and others do not – non-fiction science television production needs to be understood. Here I will detail the methods by which I analyse non-fiction television programmes so as to identify the differing representations of science within them. I then describe the methods I utilised to gain an understanding of the world of non-fiction science television production.

I will describe how I selected, sampled and analysed the television programmes in which I identify secular and religious portrayals of science. I utilised ethnographic content analysis and semiotics in order to understand how science was presented within these different programmes, and how this constituted either a secular or religious representation.

I justify my use of semi-structured qualitative interviewing as a method to understand the world of non-fiction science television production. I address the epistemological issues underpinning the interview method. I outline the debate over how the data gained in semi-structured interviews can be put to use and analysed (Atkinson 1971; Yearley 1988; Collins and Yearley 1992; Hammersley and Atkinson 2007). I argue that interviewing is a worthwhile surrogate for participation in a form of life. Interviewing members of a form of life, when carried out with the right end in view, can provide the researcher with understanding that approaches participant comprehension (Collins 1984, 1985).

The second half of the chapter offers a descriptive account of my interview fieldwork. I begin by discussing my sampling methodology. I discuss the specific challenges presented when interviewing elite groups (Nader 1972;

Ortner 2009; Mikecz 2012). My participants all had either higher or similar social status to myself, and so I had to both 'study up' and 'study sideways' I then provide details of my participants; their role and position within the world of science TV production. I describe the various sites at which I carried out my research, and the impact these different sites may have had on the quality of the data I collected.

I discuss the ethical issues arising from my research. These include the possible tension between the withdrawal of participant consent and the needs of the researcher and anonymity in a bounded and close-knit community.

Methods for Analysing Media Texts

Media analysis involves collecting some amount of media content and subjecting it to interrogation in order to understand the messages it contains. The way in which texts make meaning depends on the media from which they are sampled. Television programmes make meaning through a number of communicative modes (Machin 2007). These include speech, visual imagery and other non-talk sound elements (music, sound effects). To understand the meaning of a television programme, what messages its representations communicate, these different modes all require analysis.

The amount of content selected and the type of interrogation it is subjected to depends on the theoretical assumptions regarding media influence that the researcher makes. Researchers with a traditional understanding of cultivation theory, for instance, may adopt more quantitative approaches to the analysis of media content, attempting to assess the entire media landscape in order to understand the strength of various media messages (McQuail 2004). Large quantities of data will be collected and analysed utilising rigorously developed protocols. Validity of interpretation of this data is produced through inter-coder reliability scores. Analytical protocols are applied by a number of analysts, who should (if the protocol is well developed and rigorous) apply it to the data in similar ways. Measures of inter-coder reliability indicate the rigour of the protocol and validate interpretation.

More recent developments in cultivation theory (e.g. Podlas 2006) justify a smaller sample of texts. Individual media texts can represent issues, topics or people in various ways which will have some impact on how they are understood by their audiences. Audiences may interpret or read media content in various ways (Hall 1973), however, preferred readings can be identified and will exert some influence on audience understandings.

Ethnographic content analysis (Altheide 1987) can be applied to the textual (spoken) elements of a television programme. Detailed analysis can identify the use (and non-use) of specific words, phrases, or metaphors (Holliman 2004, Woods et al 2010), how these things are said and in what context (Hutchby 2006, Scannel 1991) and how this conveys specific meanings. Semiotic theory can be used to illustrate the ways in which images convey a complexity of meaning. What is shown on the screen (and what is not shown), how images are arranged in specific shots and how shots are ordered will convey particular meanings and shape interpretation in particular ways. The multimodal nature of a television programme means that the meaning is created through the interaction between different modes of communication. A set of images presented alongside particular words and accompanied by a particular soundtrack will communicate a meaning which will be different from the meaning communicated by any of the modes in isolation, or a different combination of content within each mode.

Ethnographic Content Analysis

Ethnographic Content Analysis (ECA) is concerned with how messages or meanings are communicated in the media (Altheide 1987). ECA acknowledges the polysemy of media texts. Authors encode texts with meaning, but different audiences (including the researcher) may decode texts in different ways. For this reason, the theoretical background of the researcher is important when ECA is employed, both during the sampling and analysis of media texts

In ECA, a theoretical or purposive sampling frame (Krippendorff 2004) is generally employed. Rather than investigating a large corpus of texts with no prior assumptions about the meanings they may contain, the researcher will be aware of a body of relevant texts. The researcher as an everyday member of the public is exposed to media messages. As a member of the public with specific expertise and interests the researcher is able to recognise media products containing messages that are worthy of closer reading. Theoretical sampling involves the researcher identifying, through preliminary reading, examples of texts which align with their research interests;

> "Relevance sampling is not probabilistic…units of text are not meant to be representative of a population of texts; rather, they are the population of relevant texts" (Krippendorff 2004, p. 119)

Once a body of texts has been selected the ethnographic content analyst is engaged in a reflexive process of data-collection/analysis, reflection and protocol refinement (Altheide 1987, 1996). Through this reflexive and recursive practise of protocol development, analysis and refinement data coding categories will emerge, merge and submerge. Meaning is assumed to be context dependent, so once more of the data is known and understood, what becomes important, what messages it seems to transmit, will shift accordingly.

> "ECA follows a recursive and reflexive movement between concept development-sampling-data, collection-data, coding-data, and analysis-interpretation. The aim is to be systematic and analytic but not rigid." (Altheide 1996, p. 16)

The prior knowledge a researcher brings with them will impact upon the types, number and characteristics of the categories which emerge from the data. A coding scheme is not developed, solidified, taught and then put into practise by a number of researchers simultaneously. Intercoder reliability is not sought. The individual researcher is the primary analytic tool during ECA.

> "Unlike in Quantitative Content Analysis (QCA), in which the protocol (coding scheme) is the instrument, the investigator is continually central in ECA, though protocols may be used in later phases of the research" (Altheide 1996, p. 16)

Televisual Modes of Communication: Speech, Image, Music

The totality of meaning present within a television programme is communicated through different modes. Analysis of the spoken language of a programme involves reading the mode with a focus on what is being said (what specific words, phrases or metaphors are used), who is saying it (presenter, interviewee, audience member, member of the public) and in what context (piece to camera, on-screen interview, voice-of-god narration). Analysis of the visual elements of the programme involves reading the mode with a focus on what is presented within an image (how is the image constructed, what semiotic resources are utilised, how do they paradigmatically connote) and how the image is contextualised by the surrounding images (what is its syntagmatic connotation). Accounting for the multimodal nature of television means combining the spoken language and visual analysis to understand how the messages communicated by a shot, sequence or entire programme are the result of the combination of what is said, what is seen and what else is heard (music, soundtrack) whilst a television programme is being watched.

Analysing the Spoken Language of Television

Spoken language is the primary mode of human communication and interaction. The spoken language of a television programme is one of the most immediate and obvious ways in which meaning is communicated. Both what is said and how it is delivered are important in defining the meaning of the spoken language of a television programme.

All spoken language on television is intended for an audience. It is "public discourse, meant to be accessible to the audience for whom it is intended" (Scannell 1991, p. 1). The vast majority of the intended audience for the spoken language of television is absent from the site at which the talk is produced (minus the studio audience if there is one, or the production crew if there is not). Television spoken language is therefore fundamentally different from a conversation between two or more co-present individuals. The audience cannot immediately and actively respond or influence the direction or content of the talk. It is also fundamentally different from forms of mass address. The audience is not 'captive' as in a lecture or sermon, nor is it a 'mass' audience in the traditional sense associated with gatherings for political oration. Television audiencing takes place in private spaces, in the homes of the audience. These are personal spaces that demand a more personal kind of talk.

As a result in all television, the spoken language is designed to communicate to an absent audience in a way which recreates the effect of personal interaction (Hutchby 2006). Television talk must appear to be addressed if not to an audience, then at least for them (Hutchby 2006, pp. 11-12). Talk of this kind is referred to as 'parasocial interaction';

> "a form of talk that is possibly quite particular to broadcasting: talk that is hearably personal while being, at the same time, specifically impersonal. It is talk that crosses the boundaries between the 'private' and the 'public' in unique ways" (Hutchby 2006, p. 12)

The spoken language of television is therefore a specific kind of communication, the communicative strength of which lies in its ability to create this simulated intimacy.

> "In ways often similar to everyday conversation, [the audience] are addressed by [the spoken language of television], invited into forms of parasocial interaction and attentive listenership, even though they remain absent from the site of its production." (Hutchby 2006, p. 14)

Spoken language can be represented on television in a variety of forms; on-screen exchanges (e.g. between professional actors in a drama or between a game-show host and contestant), interviews (e.g. between broadcasters and politicians or celebrities), direct address by individuals on screen to a studio audience or through the camera to a television audience (e.g. by a presenter or newsreader), or voice-of-god narration over displayed images.

These different forms of spoken language are designed to produce different responses in their audiences. Though the spoken language is designed to be received in the day-to-day spaces of the home, the different kinds of spoken language described above will be responded to differently. Unscripted talk between interviewer and celebrity is intended to produce familiarity, to invite the audience into the talker's confidence. The stiff and formal scripted lines of a newsreader demand respect, reinforcing the authority of the news reader and the content they are reporting on.

What is said in a television programme is as important as how it is said. What words are used, and the meanings these words convey, the use of particular metaphors and the absence of others will help to define the overall meaning of the television programme. What is said, who is saying it and in what context are all important in defining the messages communicated by a television programme.

Analysing the Moving Image of Television: Semiotics

Semiotics is the study of signs (Rose 2012). Signs convey meanings to their audience. What meaning is conveyed by a particular sign is the result of cultural and historical factors which imbue particular signs with particular meanings (Machin 2007). Signs are culturally constructed; their meaning differs from culture to culture. Saussure (2006) argues that a linguistic sign can be broken down into a signifier (the written or spoken word) and the signified (the concept or object described by that word). The object in the world the signifier and signified relate to is termed the referent. The connection between the signified and signifier is conventional[13]. There is no necessary connection between the word 'lion' and the concept of a four legged African carnivore. The connection between the signified and the referent is grounded in our shared social experience of reality. If we have no experience of four legged African carnivores in our culture, then the word lion will attach to something other than the concept of four legged African carnivores, or will be meaningless.

The clear distinction between signifier, signified and referent breaks down where moving photographic images are concerned. A photographic image of a lion is essentially indistinguishable from an actual lion (Monaco 2009). To understand the word lion, enculturation in a society which has experience of four-legged African carnivores (the referent), uses the word lion (the signifier) and attaches that word to the concept of four legged African carnivores (the signified) is required. To recognise a lion in a moving image, only the referent and signified need to be known. The viewer must be aware that four legged African carnivores exist and look a particular way but understanding of the word lion is not required. The moving image of the lion bears a more direct relationship to the actual lion than the word lion does (Monaco 2009). In this way, images speak for themselves.

This reveals one way in which images can be meaningful. An image of a lion conveys the concept of a lion. This kind of meaning is described as denotative. The denotative meaning of an image is the 'top-layer' of meaning, what the image depicts in the physical world. An image of a lion denotes a four legged

[13] In the cases of onomatopoeic words this connection is less arbitrary

African carnivore. An image of a lion (the signifier/signified) is an icon of a physical lion (the referent).

However, moving images contain more than iconic representations of physical referents. The moving image of a film or television programme conveys a complexity of meaning in other ways. Technically, the moving images of a film or television programme are comprised of many frames of still images[14]. Though it is possible to analyse individual frames to understand their meaning, when watching a film or television programme individual frames are rarely experienced individually. The viewer is provided with a stream of images which together form the moving representation of the world. Taken together, the individual frames of a film form a "continuum of meaning" (Monaco 2009). Moving images are both simpler and more complex than spoken words or written text. Their relationship to reality appears more direct, yet an image has the potential to convey, or connote, a variety of meaning.

The connotative meaning of an image is culturally defined. What is denoted in an image carries a range of associated meanings with it, meanings which can relate more or less abstractly to what is denoted. A lion in some cultures can be associated with bravery or strength. Moving images connote meaning through syntagmatic and paradigmatic connotation. Paradigmatic connotation is related to mise-en-scene. Syntagmatic connotation is related to montage. Mise-en-scene describes the way in which images are composed, what is selected to be included in a shot and what is excluded. Montage describes the way shots are ordered in time, which shot follows which in a sequence.

The mental comparison between the image which is presented and all other possible images of a similar type which could have been used connotes meaning paradigmatically. This comparison can be consciously or subconsciously enacted. An image of an old male lion can be (sub/consciously)

[14] This was the case with cameras which used physical films. More recent digital cameras construct their flow of moving images in other ways.

compared to the image of a young male lion, a female lion or a lion cub, imbuing the seen image with a particular connotation. The fact that an old male lion is shown, rather than these other kinds of lion, will tell the viewer something about how to understand or read the image, and the meaning it intends to convey. A low-angle shot of a person can be consciously or subconsciously compared with an eye-level or overhead shot and will connote different meanings about the status or authority of that person (Monaco 2009).

Syntagmatic connotation occurs through comparison between an image and the images which immediately precede and succeed it. Moving images are presented in sequence. Each seen image is contextualised, made to carry a particular meaning, by the images which surround it. An image of an old male lion connotes a different meaning if it is succeeded or preceded by an image of a pride of lions rather than a pack of hyenas. If we are presented by the former we may read the old lion as a ruling patriarch, dominating the landscape. If presented with the latter we may read the old lion as isolated and past his prime.

Alongside this paradigmatic and syntagmatic connotation, moving images connote meaning in other ways. Images can be both indexical and symbolic. Indexical images can employ metonym and synecdoche. Metonym is based around the principle of substitution. Synecdoche is based around the principle of contiguity. An image can use metonym when an object, person or thing is used to represent a related object, person or thing. An image of a lion can be metonymic of the continent of Africa. An image can employ synecdoche when a part of something is used to represent the whole, or the whole is used to represent a part. An image of a hand can represent an entire person; an image of marching feet can be a synecdoche for the armed forces of a nation; an image of the pride can represent an individual lion.

Indexical images represent a closely related, or contiguous, object or phenomena. They are iconic or denotative of a thing or phenomena which is intended to bring to mind in the viewer some other thing or phenomena. This can work on multiple levels. Images can use both metonym and synecdoche at the same time. An image of the hands of a clock can be a synecdoche for the entire timepiece, which in turn can be metonymic of the passage of time. What an image is indexical of is culturally defined. If a culture has no experiences or knowledge of clocks, then image of the hands will not signify a clock, which will not be indexical of time.

The connection between denotation and connotation of symbolic images is entirely arbitrary. The association is culturally constructed. A red cross on a white background is denoted on the English flag. This bears no direct relation to the geography or people of England. England is not shaped like a red cross. However, symbolic connotations are attached to this simple geometric denotation in English culture.

The moving images of a film connote meaning paradigmatically and syntagmatically, indexically using metnoym and synecdoche and through symbolism. The images of a film can connote meaning in all of these ways simultaneously. The way in which the images of a film are read, what meaning is inferred from them, is a result of cultural associations. Understanding the old lion amongst his pride as the dominant male, requires inhabiting a culture which associates male lions with dominance. Understanding an image of a ticking clock as representing the passage of time requires us to inhabit a culture that possesses the concept of clocks, and has made the link between the movement of their hands and time passing. The swell of pride and nationalism that an Englishman feels when he sees the cross of St. George may be quite different to emotions felt by his Welsh neighbours. Based on cultural and historical factors an image can connote a variety of abstract ideas, thoughts and emotions which have no necessary physical connection to the object of the image (Machin 2007).

Multimodality

A film or television programme contains a number of 'modes' or "mediums of communicative action" (Rose 2012) including; speech, moving image, music, and soundtrack. Groupings or arrangements of symbols within these various modes are complex semiotic systems (Machin 2007). Meaning is realised through the inter-relationship of these systems. Music can be used to connote specific emotions or feelings. It has the power to heighten the effect of images and talk, or to provide counterpoint to this effect. Investigating these modes in isolation means ignoring the interplay between them, and how meaning is produced through this interplay. When analysing television programmes the variety of modes through which meaning is made needs to be taken into account.

Methodological Strategy Employed

I employed ethnographic content analysis (Altheide (1987); (1996)) to sample and analyse the textual elements of two non-fiction science television programmes. From September 2012 to March 2013 I watched a number of non-fiction science television programmes broadcast on the BBC. My prior research into science documentaries (Mason-Wilkes 2011) led me to purposively sample *Wonders of Life* (henceforth *Wonders)* as representing a portrayal of science similar to one which I had previously identified as religious. During this time *Bang! Goes the Theory* (henceforth *Bang!)* was also aired. *Bang!* initially appeared to represent an alternative portrayal of science to *Wonders*. I selected these two programmes as my relevant sample and undertook a more detailed analysis to reveal the contrasting ways in which they portrayed science. This sampling methodology relied heavily on my prior theoretical knowledge, a key aspect of ethnographic content analysis (Altheide 1996).

After this initial sampling, a more rigorous preliminary analysis was undertaken. In order to generate the coding scheme the entire series of each programme; 5 episodes of *Wonders* (5 Hours running time) and 8 episodes of *Bang!* (4 hours running time), were viewed with no strict analytical scheme in place. Prominent elements or themes were noted. Of particular interest were what I describe as Religious and Secular elements of the portrayal of science. Following this preliminary analysis a coding scheme or protocol was established, in line with ethnographic content analysis methodology (Altheide 1996).

RELIGIOUS PORTRAYAL	SECULAR PORTRAYAL
Creation Story: Science can, and already has, provided us with a definitive account of the creation of the universe and everything within it	**'An' not 'The' account of nature:** Science can provide us with one description of the natural world, without it being definitive or necessarily superior to others. Concurrently there are multiple scientific accounts of natural phenomena and disputes between them
Explanatory Omni-competence: Science can explain everything about the universe and the things within it. Any unanswered questions which currently remain will soon be answered	**"Further research is required":** Scientific knowledge is incomplete and cannot explain everything about the natural world. Ignorance is part of science and is a motivating factor within it. Discoveries raise as many or more questions as they answer. Scientific results can be more complex than initially expected
Revealed by Nature: Scientific truth or facts come out of nature with minimal intervention by humans. Scientific truths can be easily demonstrated away from laboratories in natural settings	**Technical Skill:** Scientific truth or facts are difficult to produce and require technical skill and a particular setting – i.e. a lab – to produce. Technological artefacts are important for creating scientific knowledge or doing science. There is a process by which scientific knowledge is extracted from nature or produced,
Immutable/Unchanging: Current scientific understandings are unlikely to change. Science has achieved a fundamentally correct understanding of the universe and the things which inhabit it	**Changeable:** Scientific understanding can and will change over time. Currently held scientific beliefs may be disproved in the future or by current research
Meaning Providing Endeavour: Scientific understanding can locate humanity within a grand universal narrative and thus provide us with existential justification and psychological consolation.	**Ambiguous Endeavour:** Science can provide humanity with both positives and negatives, whether they be understandings or physical artefacts or effects.

TABLE 8

The following coding scheme with 10 categories, aggregated into 2 meta-categories was produced. These categories are concerned primarily with the textual elements of the programmes. The visual elements were then assessed alongside these text categories to understand how the visual elements add to the themes present in the talk. The coding categories are shown in Table 8.

With the coding scheme in place a more rigorous analysis of 2 episodes from each series was undertaken. I selected the first episode and the middle episode of each series. The first episode of each series was analysed as I believed it would be characteristic of the rest of the series. The middle episode of each series was chosen to see if the themes which were identified in the first episode were still identifiable. This would confirm the belief that the first episode was emblematic of the entire series, and that a consistent portrayal of science was identifiable across the whole of each series.

The 4 episodes (total 3 hours run time) were transcribed. The process of transcription has been described as a process of translation (Rose 2000). A transcript is always an approximation rather than an exact likeness (Rose 2000). What is transcribed and the level of detail that is adhered to is based upon the methodological prerogatives of the researcher. This is especially significant when transcribing television programmes. Not only are there choices to be made in regard to the transcription of the textual (talk) elements of the programmes, description of the visual and soundtrack elements also requires consideration.

The richness of the televisual media makes accurate and complete description of even a few frames both linguistically complicated and temporally demanding. Entire monologues can be dedicated to describing and analysing even a few minutes of film footage (Birdwhistell 2011). The approach I employed aligns with Iedema (2001). I noted when there was a cut between camera shots. I transcribed the talk, indicating whether talk was between individuals on screen, delivered to camera or in voiceover. What was presented visually and the other soundtrack elements that were present in each separate shot was described.

The episodes which were analysed varied in length. *Wonders* occupied an hour long slot. I transcribed from the opening scene until the end credits rolled. For each episode of *Wonders* I transcribed 58:30 and 58:31 (117 minutes and 1 second total). These transcripts were 12,205 words and 12,140 words in length. *Bang!* occupied an half-hour slot. This meant its running time was slightly less than thirty minutes. I transcribed 28:29 for episode one and 28:16 for episode five (56 minutes and 45 seconds total). The transcripts were 7,796 words and 7,964 words in length. Full transcripts of these episodes are presented in Appendix 1.

Once each programme had been transcribed, the transcripts were divided into segments of roughly 1 minute in length. I allowed for 'natural' breakages in the flow of the programme (most often cuts in sequences) explaining the variation in the length of segments. The text, visuals and soundtrack of the segments were analysed and coded for the relevant themes they contained. Sequences which contain representative examples of the coding categories will be illustrated by still frames in chapter 6 of the thesis. This also draws on Iedema (2001)

This was followed by a brief quantitative description of the results. The distribution of the coding categories across each of the programmes was investigated. This allowed me to understand the frequencies with which the different coding categories appeared within the programmes analysed. This showed which of the individual coding categories appeared most often in the different programme, revealing the specific ways in which the programmes achieved either a secular or religious portrayal. The results of this process are offered in chapter 6.

Interviewing as a Method for acquiring Native Comprehension

To understand why non-fiction science programmes represent science the way they do, I need to know how non-fiction science television programmes are made. I can understand the formal procedures of television production by reading television production textbooks or manuals. Millerson and Owens (2009) or Wurtzel (1985) could be consulted. They provide detailed descriptions of the production process for a variety of TV genres. They offer a breakdown of the different phases of production, what happens where, what resources and technical skill are required

However, a textbook provides only a sanitised description of a field. From reading a textbook I may be able to understand the formal procedures of non-fiction science television production, but the tacit rules and assumptions, the values that direct and constrain behaviour will not be visible. To understand the elements that characterise the form of life of non-fiction science television producers, I require direct access to this form of life.

Long immersion in a community, learning and sharing in its practises and discourse, provides the researcher the best insight into a form of life (Collins 1983b, 1984). Access to the form of life can equip the researcher with similar understanding as a native member. Participant observation provides the best opportunity to gain this native comprehension.

To obtain a native comprehension of the world of non-fiction science television production, ideally I would need to spend a number of years being a television producer. Barring this, a number of years embedded within the community of (and particularly the discourse) of television producers would give me similar level of understanding as a native (Collins 1984).

> "Native members, and these include the investigator at the conclusion of participant comprehension, *share* a way of life and should therefore experience it in similar ways. Thus, in principle, they should all report it in similar ways" (Collins 1984, p. 65)

However, the form of life I am interested in presents specific barriers to the PhD researcher attempting to immerse themselves within it.

Making a single hour long science television programme is a process that can often take upwards of a year to complete. This process occurs in a number of geographically disparate, and, in parts, exotic or hard-to-reach places. There are a range of people involved in the making of a programme, all of whom have their own specific roles within the process, who enter and leave at different times with greater or lesser impact on the final product. Conducting a situated ethnography or engaging in a long-form participant observation of television production presents some very particular problems. In traditional anthropology, or the lab studies tradition in STS, the site is relatively easy to identify (if not always access). A lab is (to a greater or lesser extent) physically and geographically limited, similarly a tribal village or range. In television production, instead of a single site, there is a constellation of sites where a television programme is produced. A TV programme is made in development, the pitch, the commissioning routine, pre-production, shooting, the edit. All of these phases occur in creatively, temporally and geographically distinct locations, which could be open, to a greater or lesser degree, to ethnographic enquiry.

Like a constellation, looking at any one of these sites in isolation will not provide a complete picture. Questions of where TV is actually produced, how it is made and what are the values of the people who make it will not be comprehensively answered by studying any one of these sites alone. An embedding within the community overtime could allow me access to most of these different sites, but based on the resources I had at my disposal, this was not possible. Accessing these different sites and spending enough time at each of them to gain the required native comprehension costs both time and money. Immersing myself in the community of television makers presented challenges (both temporal and financial) I was not in a position to overcome.

Interviewing as a Surrogate for Participant Observation

The open-ended, semi-structured approach to interviewing aims to provide the interviewer with as close to a native understanding of the participant's community as possible. This is achieved through the collection of interviewee's detailed accounts of their world. These descriptions provide the researcher with an insight into a world or group previously closed off to them, in the terms of an insider of that group.

> "The interviewer needs to be aware that the prime object of the interview is not to elicit details pertaining to the individual, but to tap the body of rules and understandings that comprise the individual as [skilled practitioner in a group]" (Collins 1983a, p. 93)

As more interviews are completed the interviewer's comprehension of the form of life of their participants will increase. This necessitates the iterative development of the interview schedule[15]. Within each interview, the researcher may have broad questions or themes which they wish to investigate, but the direction of the talk in the interview is reliant on the responses given by the interviewee. The interviewee is the one 'in the know', whose insider, expert knowledge the interviewer is trying to access. Questions or topics which, at the start of the fieldwork process, the researcher may have believed to have been important or relevant may well be proven unimportant or irrelevant during early interviews. Things which the researcher had not considered or had no knowledge of will arise during the fieldwork and be included in later interviews (Collins 1984).

Employing this approach mitigates the risk, inherent to more structured interviewing techniques, of asking the wrong questions (Galletta 2013). Employing a set of rigid researcher-devised questions will not allow the participant to express understanding of their community in their own terms. Specifics of the community which respondents may believe are important, but

[15] A generic version of my interview schedule is provided in Appendix 5. It shows the kinds of questions asked during my interviews, with the obvious caveat that as I state above, my interview schedule was modified continuously as my fieldwork progressed.

which the researcher as an outsider has no knowledge of, may not be allowed to come to the surface when more structured interview methods are adopted.

The extent to which talk produced in the interview setting can be considered to be a reliable account of the interviewees' world, and thus a plausible surrogate for inhabiting it, has been debated. In this next section I will discuss this debate and defend my own position in regards to the interview data I have collected.

The Nature of Interview Data

What kind of data is produced during qualitative interviewing has been debated. Two broad perspectives can be identified. On the one hand, the data collected in an interview is considered to be a reliable account of actual social phenomena. On the other, people's accounts of their action given in interviews are seen as irrelevant in explaining their behaviour in social settings (Hammersley and Atkinson 2007).

Yearley (1988) describes this debate as between actionists and accountists. Actionists argue that the accounts given by respondents in interviews can be taken (to a great extent) at face value. These accounts can be used to discern individual motivations for action. Accountists deny this. Drawing on, for example,. Garfinkel (1996) and ethnomethodological theories, accountists claim that accounts of action are concocted, after-the-fact justifications for actions. An individual's actions are determined by the interaction process itself. Thus, the motivation for an action, such as agreeing to an invitation, is viewed as "a function of the communicative system rather than of the speakers as individuals" (Yearley 1988, p. 581). Accounts of action are only able to;

> "testify to the methodic ways in which human beings are readily able to construct plausible descriptions of social action and social order" (Atkinson 1978, p. x)

Accountists with a focus on conversation analysis may thus be interested in the way in which accounts are constructed in the interview setting and the semantic and linguistic resources that are drawn upon in constructing accounts (Yearley 1988).

The contribution of the sociology of scientific knowledge (SSK) to this debate is important. SSK (e.g. (Latour and Woolgar 1986; Bloor 1991; Collins 1992; Collins and Pinch 2008) argues that scientific knowledge is a cultural product. Bloor's (1991/1976) 'strong programme' set out the tenets of symmetry and reflexivity, which are most relevant to the debate surrounding the status of interview data. Symmetry meant that the same kinds of causes could be marshalled in explanations of both true and false beliefs. Reflexivity meant that the methods of SSK could be turned back upon sociology itself. Sociological theory grounded in empirical findings could be shown to be socially constituted.

The socially constituted nature of sociology was used to criticise traditional, actionist, sociological approaches. Actionist sociology was inherently conventional. Accepting that interview data could reveal something about the actual world of interviewees was a convention of sociological practice that had no firm epistemological grounding. Collins and Yearley (1992) refuted this interpretation of the contribution of SSK.

> "How do we know that the chromatograph represents the chemical, that the respondent's answer represents his or her attitude, that the image in the telescope represents the world imaged through it? The problem is thus a general and irresolvable problem (1983, 240). What reflexivity shows is the ubiquity of this problem. It occurs in epistemological theorizing but also at the laboratory bench and in the argumentational practice of social scientists" (Collins and Yearley 1992, p. 307)

By showing that all knowledge is the product of particular social arrangements the strong programme had not undermined particular types of knowledge. Instead it had levelled the epistemological playing field (Collins and Yearley 1992). There was no 'real' truth to be discovered beyond that which is socially negotiated.

> "The mere demonstrability of the socially analysable nature of any explanatory category should not be allowed to count, by itself, as a criticism of the use of that category" (Collins 1983a, p. 101)

Or to put it another way "In all cases the validity is the outcome of social negotiation; the absence of social negotiation is not a condition of validity" (Collins 1983a, p. 104)

This justification draws on Wittgenstein's notion of meaning and use. For Wittgenstein "meaning and use are two sides of the same coin" (Collins and Yearley 1992). The meaning attributed to anything is dependent upon the use it is put to in a form of life.

Using interview data to describe individual's motivations for actions is justified as other social scientists put it to this use. This is an accepted way of going on in the social science community. Identifying the underlying values of the interviewee's community or form of life from what they say (and don't say) in an interview is also an accepted way of going on in the form of life of the qualitative social scientist. In the world of the ethnomethodologist this practice is not acceptable. The acceptable practice is to view accounts of actions as testifying to the methodic way in which humans can construct accounts of social order. Neither of these practises sits on a deeper epistemological foundation than the other. Both practises are justified and made meaningful in the specific (social) forms of life in which they are used.

> "The endlessly agonizing search for essential meanings is senseless, since the meaning of something equals its use in a form of life." (Collins and Yearley 1992, p 308)

I am justified in analysing my interview data as if they were accounts from which I can learn something about the individual motivation, and the underlying social norms and values of the community as this practise is acceptable in the form of life I work within.

Triangulation

The above justifies using interviewing as a strategy for gaining participant comprehension of a form of life. To understand how representative of the experiences of the community as a whole the information provided in a given interview is, triangulation is required. Fleck (2004), drawing on Denzin and Lincoln (1994), sees triangulation as;

> "A strategy leading to deeper understanding of the issue under investigation, and thereby as a step on the road to greater knowledge…a strategy for justifying and underpinning knowledge by gaining additional knowledge" (Fleck 2004, p. 179)

Triangulation can occur between data, between researchers, between methods and between theories (Fleck 2004). I will utilise "triangulation of data" to underpin and justify the knowledge gained in interviews. As my interviews progress, new data can be checked against data already gathered. Carrying out a number of interviews with a range of participants occupying different roles in the production process will allow me to recognise the idiosyncrasies and commonalities in different interview accounts. Identifying these commonalities in interview accounts will allow me to gain insight into the shared aspects of the form-of-life of non-fiction science television production, and ideally the formative aspirations of this form-of-life. Idiosyncratic accounts may be able to reveal where and in what circumstances the formative aspirations of science television production are violated, providing equally valuable information and aiding the development of my participant comprehension. In this way, triangulation of data helps to ensure that the account of the form of life I provide represents as closely as possible participants understanding of their own reality.

> “Techniques, such as…triangulation, are seen as a medium with which to ensure an accurate reflection of reality (or, at least, participants’ constructions of reality)” (Trent and Cho 2014, p. 653)

Purpose and Analysis of Interview Transcripts

Throughout the fieldwork process, after completing an interview I personally transcribed each recording. These transcripts formed the basis of my analysis. As suggested above, I viewed the interview process as iterative. The immediate transcription of individual interviews was the first step in an analytic process, the most immediate result of which was the development and refining of the interview schedule I used in subsequent interviews. Employing this strategy meant that from an early stage of the research I was thinking analytically about the data I was collecting. This analytic thinking informed my further data collection, but also allowed me to begin to draw conclusions about the world of non-fiction science television production. This early thinking inevitably shaped the analysis of the full corpus of interview transcripts my fieldwork produced.

Once I had completed my fieldwork, and transcribed all my interview data, I compiled a corpus of texts in the NVIVO qualitative data analysis package. NVIVO, and other computer aided qualitative data analysis software (CAQDAS), facilitate a number of qualitative data analysis approaches, however they are often particularly associated with grounded theory (e.g. Bringer et al 2006). Briefly, grounded theorists analyse qualitative data (as much as possible) from a naïve theoretical position. Analytically, the detailed deconstruction and reconstruction of data takes place. Data is coded in minute detail and then codes are combined and recombined. From this process, grounded theorists attempt to let theory to emerge from the data, rather than to using pre-conceived theory to illuminate or explain data (Charmaz and Belgrave 2007).

However, CAQDAS is also useful for less fine-grained, deconstructionist analysis, such as more traditional thematic analysis (Joffe and Yardley 2004). I utilised NVIVO's keyword query function to investigate relevant themes that had emerged during the analysis I had begun whilst conducting interviews and developing my interview schedule. Key themes identifiable across the interviews were then coded. Passages of text that contained examples of the themes I was interested in were collated on NVIVO, and transferred into MS Word documents. Here the themes which they represented were described. These coding memos were then written up to eventually form the different sections of the analysis presented in chapters four and five.

Elite Interviewing: Studying Up & Studying Sideways

I interviewed individuals working in a culturally influential industry, some of whom were in senior management positions at a world renowned institution. My interviews could therefore be characterised as elite interviews. As an academic researcher I am also in a relatively high status group, a status group similar to at least a portion of my respondents. Therefore I was faced with both the challenges of 'studying up' to my higher status respondents and 'studying sideways' to those respondents of a similar status (Nader 1972; Ortner 2009)

An elite group is, by definition, one which is accorded a high status within society (Weber 1978). There are a variety of groups from different sections of society that can be accorded elite status; community, business, political and professional (Odendahl and Shaw 2002). Elite status can be attributed as a result of the power or influence wielded (e.g. politicians (Mikecz 2012) access to or influence over financial (e.g. business leaders (Thomas 1993) or cultural resources (e.g. television buyers (Kuipers 2012) or fame or infamy within a particular society (e.g. celebrities (Kurzman et al. 2007)).

Nader (1972) argues that studying elite groups allows the sociologist to understand how power functions within, through and beyond elites. The ways in which culture is shaped, defined and transformed by the interests and values of more powerful groups can be discerned through studying elites.

Interviewing elites presents the researcher with a specific set of challenges. As a result of their high status, elites can be hard to access (Mikecz 2012). They are able to erect barriers or establish gatekeepers between themselves and the outside world (Mickecz 2012). They are visible; they are often in the public eye, yet they are also distant.

Once access is granted, elite status impacts the research process in other ways. The location of an interview can impact on the power relations between interviewer and interviewee. Interviews with elites can take place at high status places of work or public spaces, or in the home of the elite interviewee. These different locations will act to reinforce the high status of the elite.

Elite individuals are often highly intelligent or well-qualified. They are good at representing themselves to the outside world. Elite individuals are able to avoid difficult questions or control the flow of an interview. Having an open and informative conversation in an elite interview can therefore prove difficult.

Initiating contact and gaining access, designating the (neutral) location of interviews and overcoming status inequalities are all challenges the researcher faces when interviewing high status respondents. However, some of these specific challenges are alleviated when conducting academic research within the media elite. I will discuss my experience of researching media professionals; the specific challenges in recruitment and status inequalities during interviews and how I was able to overcome these challenges.

My Experience in the Field

The nature of the group I studied meant that I was confronted with the task of both studying up and studying sideways. I was interested in understanding how the process of making television impacts on the television programmes that are produced. To understand this as fully as possible I attempted to speak to individuals occupying various roles within the industry, with varying degrees of power, status and authority within the television industry hierarchy. It was hoped that these various perspectives would give me as full an understanding as possible of how the television industry works in its own terms.

Within this of course were limitations. I was focused on the editorial side of the production process. This meant that I did not speak to those individuals occupying roles in the coordination side of programme making. Though these roles are important in terms of the functioning of the programme, the creative and editorial input from these roles is to a great extent limited. Production managers, coordinators, assistants and runners are all required to make a television programme happen, but in terms of what actually appears on the screen, it is the editorial staff – researchers, assistant producers, producer-directors, series producers and executives who are responsible, to a greater or lesser extent, for this.

I began my fieldwork in April 2014. I conducted my final interview in August of 2015. In this time I conducted twenty-two interviews. The shortest interview lasted slightly longer than thirty minutes, the longest interview just under ninety minutes. In total I recorded 23hrs 06mins and 59secs of interview data. The interviews are broken down in the following way; twenty interviews with media professionals with experience of working in non-fiction science television, one with experience working within natural history television and one with experience working in science radio[16] .

[16] It was not until I began my fieldwork that the difference between science and natural history television production became clear to me. At the outset I assumed that these

Recruiting Participants

In order to recruit my participants I employed two sampling methodologies; a form of purposive sampling I describe as 'working from the credits' and subsequent snowball sampling. Both sampling methodologies were purposive. I had a specific community I wished to target and sampled people from within based on my expectation of their particular kinds of knowledge. Purposive sampling was appropriate for my research as I was interested in a small, expert community whose specific kinds of knowledge and values I was trying to understand (Robinson 2014).

My initial sampling method built on my content analysis of science television programmes. The two television programmes I analysed for this piece of research, alongside a third; *Dara O'Briains Science Club*, which I analysed for my MSc dissertation (Mason-Wilkes 2013) acted as guides as to who within the science television community I should approach. 'Working from the credits' – identifying the individuals involved in making the programmes through studying the end credits – I was able to draw up an initial list of possible respondents. My assumption was that the people involved in making these different programmes would have quite different experiences of making science TV, given the clear differences in the presentation of science I had identified during my content analysis[17]. Thus individuals involved in making the different programmes were identified as possible respondents to provide me with as broad and varied a set of accounts as possible.

After identifying relevant individuals from the credits, I was faced with the more challenging task of finding means of contacting them and requesting they participate in my research.

My strategy for finding contact details was to search the internet for private or work email addresses and telephone numbers. I was able to find my

programme genres would be made in similar ways. My interviewees showed me that this was anything but the case.

[17] This assumption was challenge almost immediately. The credits showed some individuals been involved in the production of programmes for Wonders of Life and Bang! goes the Theory.

participants using the Google search engine, but contact details were often difficult to locate. I was often presented with links to potential respondents' social media profiles, with LinkedIn and Twitter being the two sites most frequently appearing when entering search terms such as '[participant name] contact details'. I was reluctant to contact potential respondents via these more open social media platforms for two reasons.

Firstly, there were the ethical problems presented by these more open platforms. A tweet sent to a potential respondent could possibly have been seen by a multitude of others, depending on that individual's (and my own) number of followers, the number of retweets etc. This could have had serious implications for the anonymity of the potential respondent. Similarly, the reactions of others to the tweet, whether positive or negative, could have had an impact on the extent to which the respondent could be said to freely consent to my request. A scenario could be imagined where support for or reaction against my request from the respondent's or my own followers could influence their decision to participate or not.

These concerns were coupled with practical doubts about the effectiveness of contacting potential respondents via social media platforms. I felt that these modes of communication were less formal than an official work email. Twitter is an open platform, and the nature of LinkedIn promotes the building of large networks of connections, many of whom are of little consequence or import to a user. Thus, contact through these forums is potentially easy to ignore. Though an email is also easy to ignore, through contacting potential respondents via my university account it was hoped that the '.ac.uk' suffix would help to show my status as a university researcher whilst simultaneously justifying my request for an interview. Recruitment via email has also proved a viable research strategy in previous studies (e.g. Hamilton and Bowers 2006).

I was able to find contact email addresses for a small number of possible respondents in this manner. This was mostly from individuals personal websites; these sites included CV information and often "show-reel" footage;

short clips from various programmes they had worked on. However, many of the respondents I wanted to talk to, particularly those in more senior positions did not have these personal websites with contact details on. These websites are more common amongst producer-directors, who tend to spend at least some of their careers working freelance. Those individuals in more senior positions who I wanted to contact most often worked for institutions (either independent companies or staff positions at the BBC) and though they had profiles on the company websites these did not always include outward facing email addresses (this was particularly problematic for BBC staff).

One strategy which was helpful in overcoming this problem was to utilise the help of members of staff in Cardiff University's School of Journalism, Media and Cultural Studies. This is a strategy that other researchers attempting to gain access to media professionals have also employed (Ortner 2009). I had been introduced to a member of staff who teaches in the school and who is also an active factual television producer. As well as providing me with some useful contacts, she was able to inform me of a couple of 'tricks of the trade' in regards to contacting industry professionals – particularly those at the BBC – who until then I had found no way of contacting.

This ability to successfully straddle the divide between university teaching and active film-making, is, for Ortner (2009), evidence of the relative proximity of the worlds of academia and television. In the sense both are constitutive of what Elizabeth Traube has called the "knowledge classes" (Traube 1996, p. xv). Exploiting this proximity allowed me access which I may have been otherwise unable to obtain. I was subsequently able to recruit a number of individuals from within the BBC and independent sectors (or who at different points in their career had worked in both) who occupied various positions within the lower rungs of my sample of the industry[18]. The

[18] My early interviews were carried out with Producer-Directors (PDs). This is a middle ranking position in the hierarchy of the industry. In terms of my sample Producer-Directors were the most junior individuals I spoke to. The PDs I spoke to all had recent experience of working in more junior roles (researcher, senior researcher) so I could tap into this experience as well as their more recent experience further up the hierarchy.

proximity of academia and the media elite may also have helped in convincing these potential interviewees to participate

In Ortner's (2009) study of media professionals, many of her respondents were academically qualified, holding bachelor degrees, doctorates or equivalent qualifications. Ortner argues that this experience of academia helped to persuade her respondents to participate in her research as they understood the research processes and supported it as an activity. All but two of my respondents had an undergraduate degree from a British university. Around half of them had further degrees up to the level of PhD. As in the Ortner's case, this may have been influential in motivating potential respondents to participate in my research.

As well as utilising the links between academia and the media elite, I was subsequently able to utilise the close networks within the non-fiction science television production community to expand my sample. After conducting the early interviews, I asked my participants if there was anyone within the industry they felt I should talk to. This served two important functions. I was able to get an insider's sense of who was important or in the know in the community. I was also closer to gaining access to these people, as more often than not my interviewees would provide contact details, and occasionally introductions, to these (generally more senior) respondents.

Once I had been provided details of these more senior figures, I was presented with specific challenges in terms of negotiating access. The most elite of my interviewees held managerial positions at the BBC, or were science television presenters; individuals with some level of national celebrity.

In attempting to recruit these participants I was confronted by gatekeepers. Senior management staff at the BBC employed personal assistants who were my first point of contact. Fortunately, the PAs were helpful and put me in contact with relevant management staff. Even though they were accommodating, the presence and role of the PAs reinforced the elite status of the interviewees.

The gatekeepers employed by science television presenters limited my access to prospective interviewees. Many science television presenters employ television ‘agents’. My only means of contacting many science television presenters was though their agents. Where I did manage to contact agents, my requests for interviews were turned down and I was unable to initiate direct contact between myself and the potential interviewee. Fortunately, I was able to recruit some science presenters by circumventing television agents.

The science presenters I was able to initiate contact with and interview were all based at academic institutions. They split their time between academic and media work. I was therefore able to contact these presenters through their academic “.ac.uk” email addresses. Though this wasn’t always successful, in that some presenters at universities did not respond or did not agree to be interviewed, I was able to recruit three science presenters in this way.

Given that these presenters command audiences in the hundreds of thousands for their media work, it would be reasonable to expect that they would have little time to spare for a junior academic researcher. The specific nature of this media work, alongside the motivating effect of academic interest described by Ortner (2009), may have motivated them to participate in my research.

The fact that these individuals’ occupations involved the communication and/or celebration of science can to some extent explain their willingness to participate. As well as their backgrounds in academia, these individuals produce media content which promotes science to as broad an audience as possible. When approached by a researcher who is attempting to ‘scientifically’ understand their world of work, it would seem hypocritical to deny him or her that opportunity. Some of the academic work of the presenters I interviewed involved public communication of science. To fail to engage with a researcher studying in exactly that area could be seen to run counter to the ideals of this public engagement role.

It must be noted that this sense of obligation was not readily identifiable in the interview data. This came out of my reflection on the motivations for individuals in senior management positions within the BBC or nationally recognised TV personalities to give up their time to be interviewed by a PhD student. The explanation offered above is therefore conjecture.

Account of the Interview Process

A full break down of my interviewees detailing their position at time of interview and their experience in the BBC or independent sector is offered in Table 9. In this table the generic phrase "senior executive" is used to describe a range of positions at the top of the hierarchy of production (e.g. channel controller, commissioner, head of unit etc.). In some cases identifying the positions these individuals occupy would be the same as identifying them by name. I therefore use the generic term "senior executive" to ensure as much as possible anonymity for these participants.

PSEUDONYM (INTERVIEW POSITION)	POSITION AT TIME OF INTERVIEW	BBC, INDY OR FREELANCE AT TIME OF INTERVIEW	EXPERIENCE WITH BBC	EXPERIENCE IN INDEPENDENT SECTOR
B (i2)	Producer-Director	Indy	Y	Y
D (i4)	Producer-Director	Freelance	Y	Y
G (i7)	Producer-Director	Freelance	Y	Y
M (i13)	Producer-Director	Freelance	N	Y
C (i3)	PD/Series Producer	BBC	Y	Y
O (i15)	Editor	Freelance	Y	Y
E (i5)	Executive Producer	BBC	Y	N
F (i6)	Executive Producer	BBC	Y	N
H (i8)	Executive Producer	BBC	Y	Y
I (i9)	Executive Producer	BBC	Y	N
P (i16)	Executive Producer	Indy	Y	Y

Q (i17)	Executive Producer	BBC	Y	Y
S (i19)	Senior Executive	Indy	Y	Y
N (i14)	Senior Executive	BBC	Y	N
J (i10)	(Former) Senior Executive	Freelance	Y	Y
K (i11)	Senior Executive	BBC	Y	Y
U (i21)	Senior Executive	BBC	Y	N
R (i18)	Presenter	Freelance/Uni.	Y	Y
T (i20)	Presenter	Freelance/Uni.	Y	Y
V (i22)	Presenter	Freelance/Uni.	Y	Y

TABLE 9

As suggested above, the majority of my interviews were with individuals with status similar or higher than myself. Due to the nature of their work (producing programmes for mass media) a version of their life or work history is available, and actively disseminated for public consumption. Some of my interviewees are themselves public figures, or are in the public eye. The status inequality between myself and these individuals was most apparent.

To militate against this inequality, Mikecz (2012) suggests that the researcher should 'read up' on their elite interviewees before the interview. Possessing this knowledge allows the researcher to steer the interview conversation towards details of the elite interviewees life or work that are of interest. Possessing a detailed knowledge of the elite interviewee's life and work helps to reduce the tendency of the researcher to be overawed by their interviewee.

This was a strategy I found useful in my interviews. I was able to access reasonably good summaries of my interviewees CV's through websites such as *IMDB.com*. These gave me a fairly good overview of the television programmes my interviewee's had worked on and thus I was able to tailor particular questions in my interviews to suit each interviewees specific experiences.

The interviews I conducted were also influenced by the settings in which they took place. I conducted interviews at a variety of locations and in a variety of spaces, both more and less public. These various locations fell into three categories; Workplaces, Public Spaces and Residences. These spaces all offered challenges to myself as an interviewer, some unique to the specific location, some more general. A summary of the locations in which I conducted interviews and the role of the interviewees there interviewed is offered in Table 10.

LOCATION OF INTERVIEW	INTERVIEWEE'S ROLE
WORKPLACE	
BBC Broadcasting House, London	
Bookable room	Senior Executive x 2., Executive Producer
Breakout Area	Senior Executive
BBC Glasgow	
Breakout area	Executive Producer
Independent Editing Suite	Editor
Independent Production Company Office	Producer-Director, Senior Executive
University Academic Office	Presenter x 3
Post-graduate office (via telephone)	Senior Executive
PUBLIC PLACE	
Cafés	
Broadcasting House Café Nero	Executive Producer,
Royal Institution Café, London	Former Senior Executive
Independent Studio Café, London	Producer-Director
Tinderbox Café, Glasgow	Executive Producer
RESIDENCE	
Respondent's Home	Producer-Director x 2, PD/Series Producer, Executive Producer

TABLE 10

Each of these locations provided a set of specific challenges (Hammersley and Atkinson 2007). Below I will describe each location in turn, detailing how these environments impacted upon the relationship between myself and my respondents, the effects on status these environments had and also the more mundane challenges of data collection/recording/storage these various locations presented me with.

Places of Work

Broadcasting House

The interviews conducted within Broadcasting House on Portland Place require description as the design and layout of the building may have impacted upon the quality of the interview data. Visiting the building stimulates a mixture of emotions. The BBC is a world renowned television network and British cultural institution. Being allowed access to its inner workings is both a privilege and somewhat daunting. As an example of this, on two separate visits to the building I saw a popular science TV presenter and a popular natural history presenter in the foyer. I do not consider myself to be particularly overwhelmed at the prospect of interacting with TV personalities, however, it is still hard to avoid feeling one is in an important and prestigious place when these television personalities are also present.

These feelings are emphasised by the process of entering the building. Other scholars who have researched elite groups have offered strategies to militate against this tendency to be overawed by elite surroundings (e.g. Mickecz 2012). One such strategy is to arrive at the location of the interview before the scheduled time so as to familiarise oneself with the location and assert some kind of control over the space. In the case of broadcasting house this is not possible. To enter the building one is required to sign in, receive a clip-on visitors badge and await admittance through the security-guarded, electronically accessed doors. Before being granted access a member of staff from within must greet you and chaperon you into the building. On the occasions I entered the building, I was greeted and brought into the building by the personal assistants of my interviewees. All of the people I interviewed in Broadcasting House were in highly elite positions – Head of Development, Editor of Strand, Channel Controller, Head of Unit – the process of meeting them has reinforced their apparent position of prestige.

The locations within the building where I have conducted the interviews are also worthy of note. Broadcasting House has recently been refurbished, following the closure of television centre in White City, in an open plan, modernist style. The result of this is that personal offices, even for the relatively senior people I have spoken to, are very rare. Instead, there is a system where people work in front of long rows of PC terminals in large open-plan rooms throughout the building. Alongside this there are a number of bookable rooms and “break-out spaces” – areas with sofas or cushions - in which people can sit and talk, conduct meetings etc. The bookable rooms – small glass-walled rooms equipped with tables and chairs, conference calling telephones and occasionally televisions, grouped in various places on each floor – are, as a result of the lack of personal offices, at a premium. There is an internal, computerised system for the booking of these rooms. Each room has a touch-screen panel on one of its outer glass walls which shows who has booked the room and for how long. The break- out areas are likewise arranged on various parts of each floor – these do not require booking.

Broadcasting House – Breakout Spaces and Meeting Rooms

Breakout Space

Three of the four interviews I conducted took place in the bookable rooms. One took place in two of the breakout spaces. The reason this interview took place in two of the breakout spaces serves to highlight their unsuitability for conducting qualitative interviews. Broadcasting House is laid out along an open plan design. The breakout spaces are arranged at various points along broad corridors and near communal kitchen areas. As a result of this there is a high level of background noise and general through traffic. After conducting around 10 minutes of an interview in one of these spaces on the 7th floor of the building the background noise was added to as another group of people sat near to myself and my interviewee and began a loud discussion. This resulted in the interviewee suggesting that we found a different space to continue the interview. We moved to the 8th floor of the building and found an unoccupied space filled with circular booths. The 8th floor of the building presented its own problems however, as this is where the BBC Radio 1 studios are located. This meant that periodically as people entered and exited the studios bursts of music or talking from the Disk Jockey could be heard.

The open-plan nature of the spaces in which these interviews were conducted meant that I had to contend with the kinds of distractions any interviewee doing fieldwork in a public space faces – background noise, other people's conversations etc. Added to these more common concerns was the further level of distraction, which has been described above, of being in a high-status place where it is not unlikely that one will interact with (or at least see and hear) well-known television personalities or celebrities – being next to the Radio 1 studios while conducting this research is suitably emblematic of this issue. This fact, as has been previously suggested, added to the sense of being in a distinct and high-status environment, which by association further raised the status of my interviewees.

Meeting Rooms

Both the more mundane and specific distractions presented by conducting my interviews within Broadcasting House were ameliorated when conducting my interviews in the meeting rooms. Distractions during these interviews were much less of a problem and I was able to complete the bulk of these three interviews without major problems. These rooms were more problematic towards the end of the interviews. Two of the interviews I conducted in these rooms had to be cut short as people were waiting outside to use the rooms from the start of the following hour. In the first case this was not too much of a problem as I had managed to cover the majority of what I intended before we had to vacate the room and was able to clarify a couple of points with my interviewee as they showed me out of the building. The second time this happened however, I lost the opportunity to ask a number of questions that I would have liked. The interview did not begin until around twenty past the hour – therefore I only had around forty minutes to talk to this interviewee, meaning I was not able to ask everything I would have liked.

This interview also suffered from a poor rapport between me and the respondent. The respondent was one of the most senior people I interviewed. I managed to develop a good rapport with other respondents in senior management positions, but from the very start of the interview there was a sense that I was, to a certain extent, wasting the time of my respondent who did not seem as fully engaged as my other interviewees.

These problems – the noise and distractions presented by the breakout spaces and the time-limit enforced within the bookable rooms – will have impacted my data to a greater or lesser extent. In the most severe case this reduced the length of an interview with a potentially key respondent by around a third.

This is not to say I lost a third of the data from this interview, but at least the possibility of gaining some interesting insights from this time was lost.

Independent Production Company Offices

I conducted three interviews at other places of work; two at independent production company offices and one at an independent editing suite. These experiences were broadly similar, and contrasted with my experiences at the BBC to some extent. All three interviews took place in central London. The entrance procedures were much more informal than at the BBC. On each occasion I entered a non-descript office building, twice by being 'buzzed-in' using an intercom system, and once being allowed access by a ground floor receptionist. I made my own way to the floor where my respondent was based and, on two of the three occasions, was then greeted personally by my respondent on entering their company's office space. On the other occasion I was shown to the editing suite where my respondent had been working and asked to wait by a receptionist as he was out for lunch. This respondent contacted me shortly after the scheduled interview start time via text message to ensure me that he was on his way to the interview after being delayed at the post office. All of these interviews took place in private rooms within these offices, two in meeting rooms and one in an editing suite. Unlike at Broadcasting House, access to these rooms was not so tightly time-restricted and thus I was able to talk to these respondents for as long as I needed. These rooms were also free from the distractions of the more open-plan spaces at Broadcasting House and the more public spaces described in later sections.

In all of these interviews I was able to establish a good rapport with my interviewees, and all provided me with more than the just the interview during my time with them. The first provided me with a number of development documents; pitches, film treatments, shooting scripts in various stages of development. The second, the editor, briefly showed me around his work station, at which he was editing a science documentary, showing me (very briefly) the hardware he used, helping to contextualise the interview talk. The final respondent, an independent commissioning editor, provided me with DVD copies of two programmes her company had produced, stating that they really summed up her companies attitude to science programming.

The relative position in terms of seniority of my respondents is worth noting here, as this may have gone some way to adding to the more relaxed feel of these interviews. One respondent was a producer-director, one an editor, both relatively junior positions in the hierarchy of television production compared to some of my other respondents. The third respondent was more senior – an independent commissioning editor – but even so, the more informal meeting procedure seemed to help develop a greater sense of equality between the respondent and myself, aiding the interview rapport.

Academic Offices

Three of my interviews took place in academic offices on University campuses. These interviews were with presenters, some of my most high-status respondents. The relative status of these respondents was a result of their celebrity. Two of the interviewees were men who had appeared on network television consistently for around a decade in science television series. The third was a female presenter with over five years' experience of presenting on network television. Though not at the absolute pinnacle of scientific celebrity these interviewees were well known and recognisable.

Despite this relative status imbalance, during all of these interviews I was able to develop good rapport with my interviewees. Though initially only offering me half an hour in which to interview him, I was able to talk to my first respondent for almost an hour, and was only forced to conclude by the arrival of his colleagues for a subsequent scheduled meeting. I was able to formally interview my second respondent for over an hour, after a less formal chat over lunch. The third respondent was also very welcoming and understanding when my audio-recorder temporally malfunctioned at the start of the interview. I was able to spend more time with these respondents than I initially expected.

As well as being science TV presenters, all of these respondents held tenured lecture or professorships at UK universities. Part of the good rapport I was able to develop with these respondents may have been due to our shared academic credentials (Ortner 2007). The location in which the interviews took place may also have helped facilitate open and engaged interview talk. Stephens (2007) has suggested that talking to academics in their offices, particularly as a PhD student or young researcher, can be helpful for the researcher. As academics are used to similar kinds of interactions in similar locations with their own PhD students they can be more relaxed and open when talking in their offices than would be the case in other locations. As a PhD, student I have experience of talking to more senior academics in their offices, so these interviews were made much less daunting or unfamiliar for me by the location. This familiarity for both respondent and interviewer can be helpful, in that the respondents are more willing to open up and talk and the researcher is better equipped to listen.

Stephens (2007) argues there can be a tendency for the interviews with academic respondents to get off topic. Senior academics are likely to take control of the interview and move the talk away from areas which the researcher is concerned with (particularly when technical topics in which the respondent possesses an expertise are under discussion). I was interested in less theoretically demanding aspects of work (Stephens focus is macroeconomic theory) and was able to maintain the focus of questioning, whilst pursuing novel lines of enquiry relevant to my research which my respondents responses prompted.

Public Spaces

Cafés

I conducted four interviews in cafés in different parts of the UK (Cardiff, London, and Glasgow). All of these cafés were in large, cosmopolitan cities (as opposed to quiet, rural areas) and thus have presented a specific set of challenges to the researcher. A café is a public space where the presence of other members of the public is likely to have an impact on the interview.

The public nature of a café may impact on what is being said by the respondent – they may not want to discuss issues they feel are more personal or possibly compromising to their reputation or the reputation of their profession as a whole, for fear of being overheard. Interruptions are more likely, as the space is much less controllable or predictable than a more private space such as an office or residence. Distractions are also an issue. These can affect both the respondent and interviewer. General background noise can be a hindrance in the maintenance of good rapport – if a respondent's answers are difficult to hear in a noisy café then it is more difficult for the researcher to follow these answers up with probes. The researcher may have to ask for things to be repeated, interrupting a respondent's train of thought.

This issue of noise also impacts on the recording of data. Audio-recording interviews in particularly noisy environments runs the risk of losing some of this data as the recorder cannot distinguish interview talk from the background noise. This was of particular concern for me during the bulk of one interview and a portion of another. During both these interviews the levels of background noise rose to such a level that it was difficult to clearly here my respondents talk. Here the particular nature of the group I was researching within, fortunately, helped to mitigate this problem. Both the respondents during these interviews had first-hand experience of sound recording in noisy environments (a necessary skill in television production) and both explicitly asked me about the sound levels and whether my recorder could pick up their talk. They subsequently adjusted their position in respect of the recorder and spoke more loudly and clearly to ensure both I and the recorder could pick up what they were saying.

Residences

Respondents Homes

I conducted four interviews in respondent's homes. There are a number of issues conducting interviews in respondent's homes, which can have both positive and negative effects on the data which is collected.

Respondents can feel more comfortable in their own homes – they are in a place which they are familiar with and may thus be more relaxed and willing to discuss personal or controversial topics. The space is often relatively private, so confers the same advantages other private spaces such as offices or meeting rooms do – a lesser chance of distraction, less background noise. However, this is not always the case, especially in a family home. During two of the interviews I conducted in respondents home, my respondents were called away to deal with young children, disrupting the flow of conversation.

Similarly to speaking to a respondent in their office, though the respondent themselves may feel more comfortable, for the researcher it can be more difficult. It is not possible for the researcher to survey the space beforehand and rearrange it to their liking

Though private residences can be more conducive to a focused, distraction free discussion, there are also attendant risks involved. Visiting a respondent in their home can place the researcher in a potentially risky situation. Fortunately, I was not placed in what I would describe as a risky situation during any visits to my respondents homes. All the respondent's homes I visited were in what could be described as affluent areas, in the suburbs of London, the Home Counties or south west of England. Compared to other potential locations for qualitative research (e.g. Bourgois 2003; Goffman 2009) these areas presented very minor risks to my personal safety.

These types of locations, however, can provide a different set of challenges – similar to that presented by interviewing at broadcasting house – of status. As mentioned the houses I visited were in affluent areas and were all detached or semi-detached, of good size and giving the general impression of being fairly expensive. This can add to the prestige or status of the respondent, suggesting their position is well-paid and important. This can affect the status relationships during the interview, and subsequently the quality of the talk.

Ethics: Participant Consent and Withdrawal of Consent, Use of Interview Data, Anonymity

Conducting qualitative research presents ethical challenges. These challenges centre on the issue of potential harm. This includes harm to the research participants, the researcher and any organisations to which either are affiliated.

During my research the risks of serious harm to myself or my participants was minimal and neither I nor my participants were ever placed in a 'risky' situation beyond which would likely be experienced in normal life. The lack of risk was both a function of the group I was studying and my own embodied identity as a researcher. My participants were all professionals who I interviewed for the most part in professional setting about their professional lives. There was minimal chance of discussing sensitive topics which may have caused emotional harm to my participants. The interviews were either conducted in open and visible public spaces, in well-populated office buildings or respondents homes. The homes of the respondents I visited were all in affluent, suburban or rural neighbourhoods. In terms of my embodied identity I am a young, white, middle-class male researcher of larger than average build and was never placed in a situation where I felt at risk of physical or emotional harm. However, there were some potential sources of harm to myself and my participants, and I took steps to militate against these potential risks. For myself, this included the potential harms of working as lone researcher. For my participants, issues of confidentiality, consent and the withdrawal of consent were most relevant.

Minimising Potential Harm to the Researcher

Whenever I travelled to conduct an interview I informed both my partner and family members of where I was travelling to, the specific location of the interview and my predicted time of return. I carried a mobile phone on me to all interviews, and made arrangements to contact my family members or partner after I had conducted the interview. If I failed to make contact, I had arranged for my partner or family member to contact the relevant authorities.

Minimising Potential Harm to Participants

Confidentiality

Before beginning an interview I provided my participants with an information sheet and an informed consent form (copies provided in Appendix 2). The information sheet provided them with an outline of my project and how I was using and storing the data I collected in the interview. I allowed the interviewee the time to read through the information sheet and ask any questions they had regarding the research. The informed consent form provided a summary of the points on the information sheet and required the participant to elect to have their real identity used in the final document or to have their identity anonymised. Often the participant would ask if their choice was significant in terms of the findings of my research and I would explain that it was not, and they were free to choose either option. Eight of my participants requested anonymity and fourteen stated they would be happy for their real identities to be used

As I received some requests for anonymity and other requests to use real identities, I have a further problem to contend with. In a small group or community satisfying both requests for anonymity and for the use of real identities can be problematic.

Due to the small nature of the community, and particularly the limited number of certain (more senior) positions, the anonymised individuals may be identified through the fact that they are not the non-anonymised individuals. If, for instance, three out of four BBC executives are happy to have their real identities used, one is not and I speak to all of four them, it is a simple exercise to deduce the identity of the fourth.

As a result I elected to anonymise all data throughout the thesis. When using direct quotes I give the position of the speaker and use a set of pseudonymous initials to differentiate between individuals occupying the same role. However, even using this process of pseudonymisation, it is not always possible to guarantee complete anonymity.

My sampling methodology meant that many of my respondents had knowledge of some of the other individuals involved in the study. Interaction within the community, occurring without my knowledge, could have revealed the identities of my participants to a large section of that community without my knowledge.

Knowing if an individual participated in a study is not the same as knowing what they said in the interview. However, individuals who requested anonymity may become identifiable from my use of interview data in the thesis. Speech style (which I attempted to faithfully transcribe), line of argument, expressed opinions or described past experiences may allow other members of the community to identify the interviewee from quoted material.

Before beginning the interview I would then explain that due to the small and close knit nature of the group I was interviewing I may have to anonymise all the data even if a participant was happy for their real identity to be used, and that it may still be impossible to guarantee complete anonymity. Participants verbally expressed their satisfaction with this strategy.

It is worth noting that in comparison with other qualitative research, my interviewees were possibly better able to understand these issues of confidentiality and consent. Being elite members of the media establishment placed my respondents in a unique position, with practical experience of dealing with many of the ethical issues I faced e.g. reducing potential harm to the contributors to their programmes[19].

Post-Interview Adjustment

Collins et. al (2016) have shown the different ways transcribed and audio-recorded versions of the same talk can be perceived. Transcribed accounts which include the "ums and ahs" or verbal ticks of speech, as mine did, can be perceived as uncertain or lacking authority. This can lead interviewees to feel they are being misrepresented when they see their transcribed talk quoted in a final document. This has caused problems for Collins in the past (Collins et. al 2016). I wanted to ensure that my participants had given as clear an account of themselves as they could, therefore I offered all a copy of the transcribed interview. Eight interviewees requested a transcript. I encouraged them to suggest any changes they felt necessary, however no changes were suggested.

Withdrawal of Consent

I allowed participants to withdraw their consent for me to use their data from the time the interview began until March 2016. This was six months before the intended date of completion for my thesis and it was considered that by this time the process of analysis would be more or less finalised. After this date, the disruption to the argument of the thesis would be too great to allow withdrawal of data.

This ethical issue raises an important epistemological point. In a quantitative study, when a participant requests that they withdraw their information it is a relatively simple task to remove it. Their data is deleted from the dataset and statistics recalculated with their data absent. In a qualitative study the removal of data is less straightforward. As the analysis is interpretative and

[19] A number of my interviewees described an important consideration when making science television programmes was ensuring as much as possible that contributing to a programme did not adversely impact the career or reputation of scientific contributors.

the researcher is the primary analytical tool, removing data from the analytical framework once it is constructed is difficult. If a particular participants data influences the researchers thinking in a particular way it is very difficult, if not impossible, to retroactively change this line of thinking.

Allowing participants to withdraw their information from a qualitative study therefore can only involve removing direct quotations and attributions. If a participant, after taking part in an interview, decided that they did not want their data to be used, my planned strategy was to not include any direct quotations from their interview in the final PhD document, and attribute to them nothing directly. This accords with the advice provided by members of the KES research group and builds on the interview code of practise developed by Collins (2014). Fortunately, no participants requested to withdraw their data.

Conclusions

The preceding discussion has set out some of the major methodological issues faced in this project. I have described the methods I used for analysing media content. I used ethnographic content analysis alongside semiotic theory to sample and analyse two non-fiction science programmes, *Wonders of Life* and *Bang! Goes the Theory*.

I have justified my use of qualitative interviewing, arguing it is the most appropriate method available to me to develop the understanding of the form of life of TV professionals. Temporally extended, immersive participant observation may provide the researcher with the most thorough participant comprehension. However, as previously stated, I lack both the time and financial resource to undertake this extended immersion. Thus, qualitative interviewing has acted as a surrogate for this lengthier, more resource-hungry process. It has provided me with a level of participant comprehension possession of which allows me to describe and analyse some of the features of the form of life of non-fiction science TV production. I have defined my epistemological position in regard to the interview data I collected. I am able to treat the accounts of my participants as faithful descriptions of their world as it is an acceptable way of going on in the form of life of qualitative sociology.

I have discussed the challenges specific to conducting fieldwork amongst elite groups. The challenges faced when interviewing high-status individuals have been described. These include problems of access and power-relations before, during and after the interview. I have discussed my experience in the field, providing information about my participants, how they were sampled and where the interviews took place. The dynamics of the spaces within which the interviews were conducted will have had an effect on the attitude of myself and my interviewees, their willingness to discuss particular issues and my willingness to probe in certain areas. This will have had an impact on the data I collected. The challenges faced in studying-up when interviewing certain respondents was not so evident when interviewing other, relatively low status, interviewees. Here I was able to draw on some of the advantages presented by 'studying sideways', that is studying individuals with similar backgrounds, life-histories, academic trajectories and experiences, who shared similar social status to myself as a researcher.

I have discussed the ethical issues inherent to the project, including the anonymity of participants in research on a small community, the use of transcribed interview talk post-interview, and the tension between participant withdrawal of consent and the requirements of the researcher.

The above serves to justify my decision to conduct the research in the way I have. It shows how I have understood the nature of the data I have collected and my reasons for collecting it. It details the challenges faced in this kind of research and how I was able to militate against these challenges. It contextualises the analysis that is to follow and legitimises the conclusions that will be drawn from it.

CHAPTER 4
MAKING A NON-FICTION SCIENCE TELEVISION PROGRAMME

To understand how the competing demands of non-fiction science television production are negotiated and where and in what ways institutional, structural and genre pressures are most keenly felt an understanding of the process by which a non-fiction science television programme is made is required. In this short chapter, I will provide an account of the making of a non-fiction science television programme. I will describe the four phases of production; development, pre-production, filming and post-production. I will show which roles are likely to be involved in each of these phases, and what responsibilities each role carries. I will present flow-chart style diagrams to provide a visual representation of the various roles involved at each stage of the production process, the responsibilities the different roles carry and the relationships between the different roles. This will be, by necessity, a brief and generalised overview of the process of production. In reality, no two films will be produced in an identical way. However, in providing this generalised account I will be able to highlight some of the most salient aspects of the production process implicated in my explanation of how and why the different representations of science that I identify in chapter 6 are producible. I will provide this account, before turning to a more detailed discussion of the demands and pressures of non-fiction science television production, and how they are negotiated, in the following chapter.

The Structure and Provenance of the Account

The early portion of the majority of my interviews was dedicated to discussing with my interviewees the details of the production process. I asked each of my interviewees about the responsibilities of their current role (and the roles that they had previously inhabited) within the production process; at what phases within the process they were involved, what they were expected to do and not to do and their level of influence and impact during their involvement. The account provided in the following sections of this chapter comes out of this interviewing.

A similar account could have been developed by studying television production textbooks. Millerson and Owens (2009) or Wurtzel (1985) lay out in some detail the technical and stylistic considerations made during the production of television programmes; which roles are involved at what times and with what level of input and responsibility. However, as suggested in the previous chapter, if I had only consulted the textbook I would not have had access to the tacit rules and assumptions of non-fiction science programme making. To really understand non-fiction science television production I needed to understand these tacit rules and assumptions, to gain an understanding as close as possible to that of my respondents. Asking questions about the processes of production thus served a number of purposes.

Doing so early in my interviews allowed me to establish good rapport with my interviewees. I found that asking interviewees about a topic about which they were very knowledgeable encouraged them very early in the interview to talk openly and at length. This generally led to rich and informative talk throughout the interview, from which my understanding was improved. What I was also able to do once I had gained these accounts of the production process was compare them with the accounts I had from textbooks. Drawing this comparison allowed me to recognise the similarities, and as importantly the differences between my interviewees' and textbook accounts. In recognising and examining these similarities and differences some of the less explicit rules that guide the production of non-fiction science television production became visible.

As my field-work progressed my understanding of the production process developed. What this often meant was that I increasingly understood that there were aspects of the process about which I lacked a good understanding!

For instance, during my fieldwork it became clear that I lacked detailed knowledge of the development phase of production. Early interviewees provided some description of the development phase, as outlined in the following;

> Senior Executive I: "I'm going to brainstorm tomorrow about ideas, an ideas brainstorm to come up with some new ideas so I'm very active like that, and there's an expectation of that, especially in development, where there's a constant churn of ideas… last year I ran a development team for a year, so I was in charge of basically, there was a big team of maybe 10 people, and all you do in development is, you know, it's right treatments, and then, I was head of development so I was kind of writing some treatments but mostly managing other people writing treatments"

> Executive Producer P: "The bigger companies where they have people, development teams, they study what the broadcasters ask for, they look at the shows the broadcaster's made, they look, they analyse, and they all sit around in development meetings and then they try and come up with ideas that they think will fit the, what the broadcaster's looking for and blah blah blah and then they pitch them and they, and that is a model that a lot of people use"

My attempts to gain more knowledge of this phase of production from these interviewees lead to them suggesting I speak to someone else with more experience in the area to help me better understand this aspect of the process. Eventually I was able to interview an executive producer who specialised in programme development. This executive producer gave me the following description of the development process, a much richer and more detailed account than previously provided, which helped me to fill important gaps in my knowledge.

> Executive Producer H: "So in development I've run a team of producers and researchers and what the team does, is we would have a weekly ideas meeting where we come up with ideas,

> they're often shaped by slot, so if we know it's a BBC2 9 o'clock slot, maybe a 3-parter, that will steer us in particular ways, another major thing that steers what kinds of ideas we come up with will be whether it's a domestic idea as in it will only be shown on the UK or whether its international and that is a big influence for us because actually a lot of the series we make, we can only make them if we get international co-production money…..we'll often come up with just a couple of lines which is more to do with the title and what, the big critical thing we're always thinking about with ideas is what's in it for the audience, what are they going to either learn, come away from, what's the sort of knowledge they'll learn, or what's the emotion we're trying to elicit from watching this programme? …..so you're trying to decide either whether you're going to go for something like, I mean we call it sort of awe and spectacle where it's the images that have got to be second to none and we'll often be talking about specialist cameras or how could we get images that have never been seen before or it'll be journalistic in that there's some very new piece of science we want to get across and sometimes it much more thesis driven, which is that you know we haven't done a series on the senses for example for a long time and we might try and work out how we would go about it, and then basically, members of the team, researchers or producers will write up an idea which I'll read and members of the team will read and work out whether it's going the right angle, whether it's got enough of the, sort of, the juicy facts in it or the emotional drive, and then my job with other exec producers in the science department is to pitch those ideas first of all to a science commissioner and then they will hone the idea or give us feedback and then we then pitch it with the commissioner to the channel controllers, so for BBC 1, 2 or 4, and then if that's all going well then we will also go and pitch to international co-producers so there are various points in the year and various contacts that we have in order to raise extra money to fund some of these ideas"

It is from the kind of information provided in the above quotes that I constructed the synthesised account detailed below. Though this kind of data also helped me to understand a range of other important analytic themes which I pursue in my analysis in chapter five, from asking these kinds of questions I was able to gain a greater understanding of how specific aspects of the production process proceed. Through accumulating data of this kind, I was able to gain an understanding of the production process as a whole – the requirements of its different phases and the responsibilities of those involved during each phase. By synthesising the commonalities apparent in the accounts of my different interviewees I provide below a generic sketch of the production process which will be illuminated in much greater detail in chapter five. The account in this chapter is by design generic because of the detail I provide in the chapter which follows it. In this way, chapters four and five work in tandem. Without the necessarily brief sketch provided here, the much deeper and more fine-grained analysis provided in proceeding chapter would lack context. Without the detail provided in chapter five, the account provided here lacks meaningful detail.

Development

Development is the first phase of television production. Independent production companies, television channels or networks[20] will generally employ a development team. A development team consists of a head of development working with a number of subordinate development producers. The development team's task is to generate a constant stream of ideas for new programmes. This creative process is stimulated in a number of ways. To keep abreast of any new scientific discoveries or 'newsworthy' science stories newspapers, science magazines and websites are consulted regularly. Contacts at universities or organisations like the Wellcome Trust or private enterprises are maintained and will be consulted to provide information on new scientific developments which could provide the basis for a film. Moments of historical scientific importance will be identified and provide justification and material for programmes. For instance, 2009 was 150th anniversary of the publication of Darwin's *On the Origin of Species* and the BBC made a series of programmes celebrating the occasion. Science television anniversaries will also be influential in the development of new programmes. Science television is cyclical, with similar, popular topics being covered at regular intervals. Ten years is considered a reasonable gap between

[20] In-house development of science documentaries in the UK generally only occurs at the BBC. With recent cuts to BBC budgets in-house development is now under threat.

programmes of a similar style on a similar topic. The 2010 broadcast of Brian Cox's *Wonders of the Solar System* was scheduled just over ten years after the 1999 series *The Planets.*

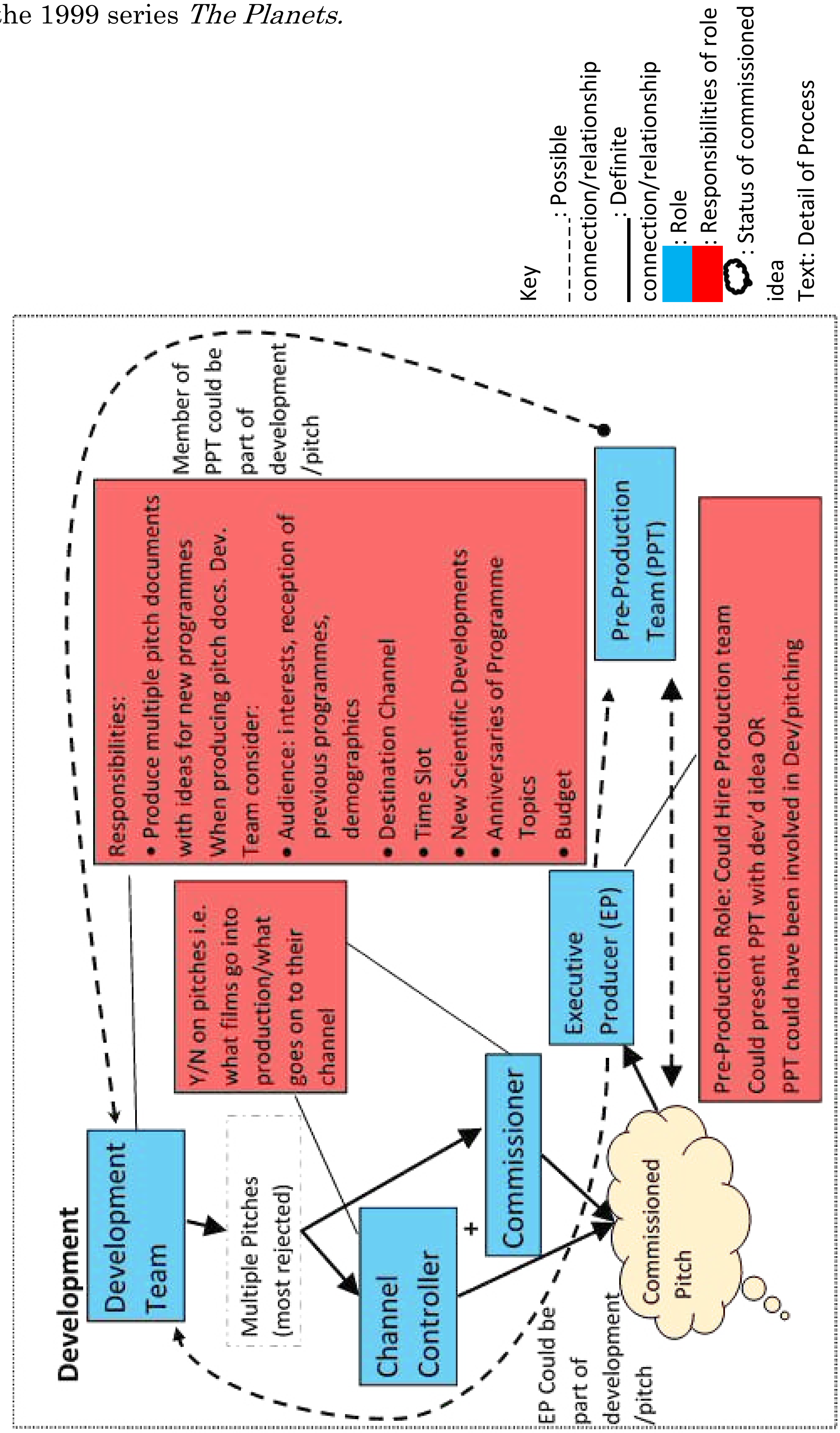


FIGURE 1

Fig. 1 outlines some of the important roles involved in the development phase of production. It shows how different roles are related in the hierarchy of production, and what responsibility each role carries.

Other considerations when generating programme ideas include audience reception to previous programmes; the demographic make-up of the intended audience for a new film; intended broadcast channel and time slot and budget. Budget will impact the production values of the film, what can be filmed, in what kind of location using what kind of equipment and 'talent' (i.e. the presenter/s). These latter considerations will impact the scope or 'angle' the film adopts. This boils down to what the film focuses on, how it communicates this specific bit of science to this specific audience in a way which will engage and be entertaining.

Development produces a stream of ideas for films, each with a unique angle, aimed at a different audience on a different channel at a different time. Promising ideas are written up into a pitch document or proposal; a short, compelling account designed to get the programme commissioned. At the BBC, a 'two-tick' commissioning system is operated. Pitches are presented to both a channel controller and domain specific commissioner (for non-fiction science programmes a Science and Natural History commissioner) who must both agree to commission the film. The majority of pitches get rejected, but if the channel controller and commissioner both like the pitch and can find space for it in the schedule it will be 'greenlit' - provided with a budget and put into production.

What happens next can vary. Historically, a producer or executive producer would have pet projects or favoured scientific topics which would provide the bulk of the material for their films, and they would be involved from development to finished programme. This is increasingly uncommon now, with professional development teams as described above doing the development work. However, some executivess or PDs will still be involved in the entire process of developing, pitching and producing a film. In this case key roles in the production team will already be in place.

More common now is the greenlit pitch being passed onto an executive producer who has had limited involvement in the development process. Their role is to put together a team to get the programme made. The executive producer will hire a number of people at this point, the most important of whom for the editorial content of the film are the Producer-Director and Researcher[21]. Once these members of the production team have been hired, the film moves into pre-production.

Pre-Production

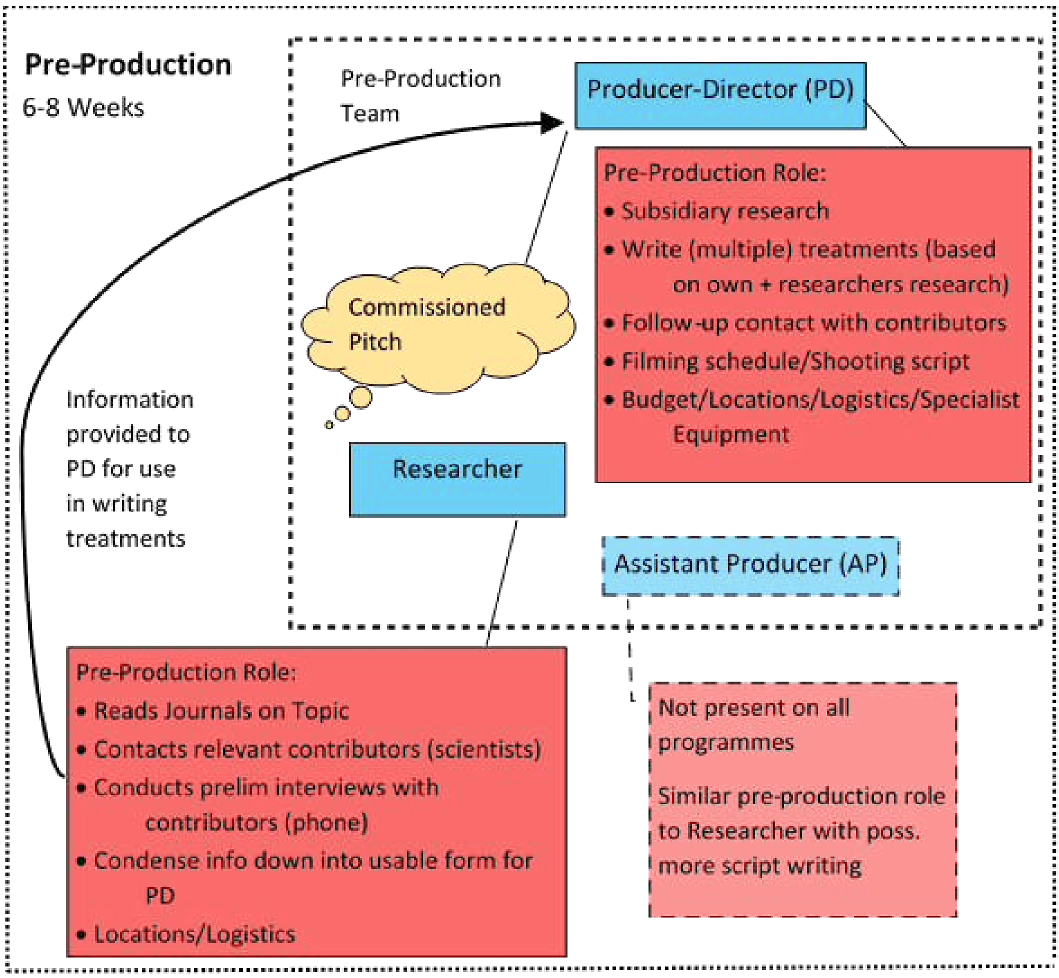


FIGURE 2

[21] Some programmes, depending on their scale and budget, will also employ an Assistant Producer (AP). Their responsibility lies somewhere between Researcher and PD, doing some research but with more editorial input.

Fig. 2 provides a visual depiction of the pre-production phase. Pre-production on a science film normally lasts for 6-8 weeks, and can sometimes run to three months. During this phase the researcher and producer director (or PD) do the bulk of the work but have different responsibilities.

The researcher's main aim is to gain a working grasp of a scientific topic, subject or field in usually less than twelve weeks. The researcher must then be able to condense this new knowledge and understanding into a format usable by the producer-director.

The researcher will consult relevant scientific journals around the topic of the programme, contact scientists in the subject area or involved in the new discovery (if that is the topic of the programme) and conduct preliminary (telephone) interviews with relevant scientists. This has two functions. Interviewing scientists provides the researcher with subsidiary information about the programme topic, confirming findings from other research or adding to their stock of knowledge. From these various sources the researcher gains a knowledge of the scientific subject. They are then able to provide the PD with an overview of the topic, highlighting the most salient aspects for the film.

Through their initial phone contact, the researcher is also able to assess how good a scientist is at communicating their ideas, if they are easy to understand and whether or not they speak clearly and compellingly. This has nothing to do with gaining knowledge of the scientific topic, it is a communicative criterion. The researcher must be able to tell the PD whether or not including a scientist in the programme will make the programme more or less clear, more or less engaging and ultimately produce better or worse TV.

The producer-director, though undertaking their own subsidiary research alongside the researcher, is primarily concerned with the narrative and aesthetic elements of the film. They will write multiple 'film treatments' (loose, but increasingly more detailed descriptions of the film which will form the basis of the script and shooting script[22]) based on the information the researcher is giving them. The PD will make follow up contact with potential scientific contributors (based on the researcher's suggestions) to judge the contributors appropriateness for TV.

The PD's main objective is organising the scientific information, given to them by the researcher and discovered through their own research, into a 'TV-friendly' narrative form. This involves writing the words in the script, which will be spoken either in voice-over or by a presenter if there is one. From their own and the researchers telephone conversations, the PD will also have a fairly good idea of what they expect their scientific contributors to say, and will write this into the script. Making scientific information 'TV-friendly' also involves working out what to film, how to visually represent the information in a compelling way. This may include the use of specialist equipment or CGI, but will definitely involve filming something, somewhere with some specific intent. It will also involve recording sound alongside what is being filmed, either what is being said by the people on screen or other inconspicuous but important background noise. The PD has the logistical responsibility (alongside the executive producer and production manager) to arrange for and hire this equipment and the skilled professionals (cameramen, lighting, sound-recordists) required to operate it.

At the end of pre-production, the PD will have developed a fairly tight shooting script which details what will be filmed, roughly what will be said by the contributors who are being filmed with a rough idea of how this will be held together by voiceover. Once this is prepared, filming begins.

[22] The script at this point gives a rough indication of what will be said by contributors, in voiceover and by the presenter if there is one. The shooting script provides an indication of what will need to be filmed – the visual elements of the programme.

Filming

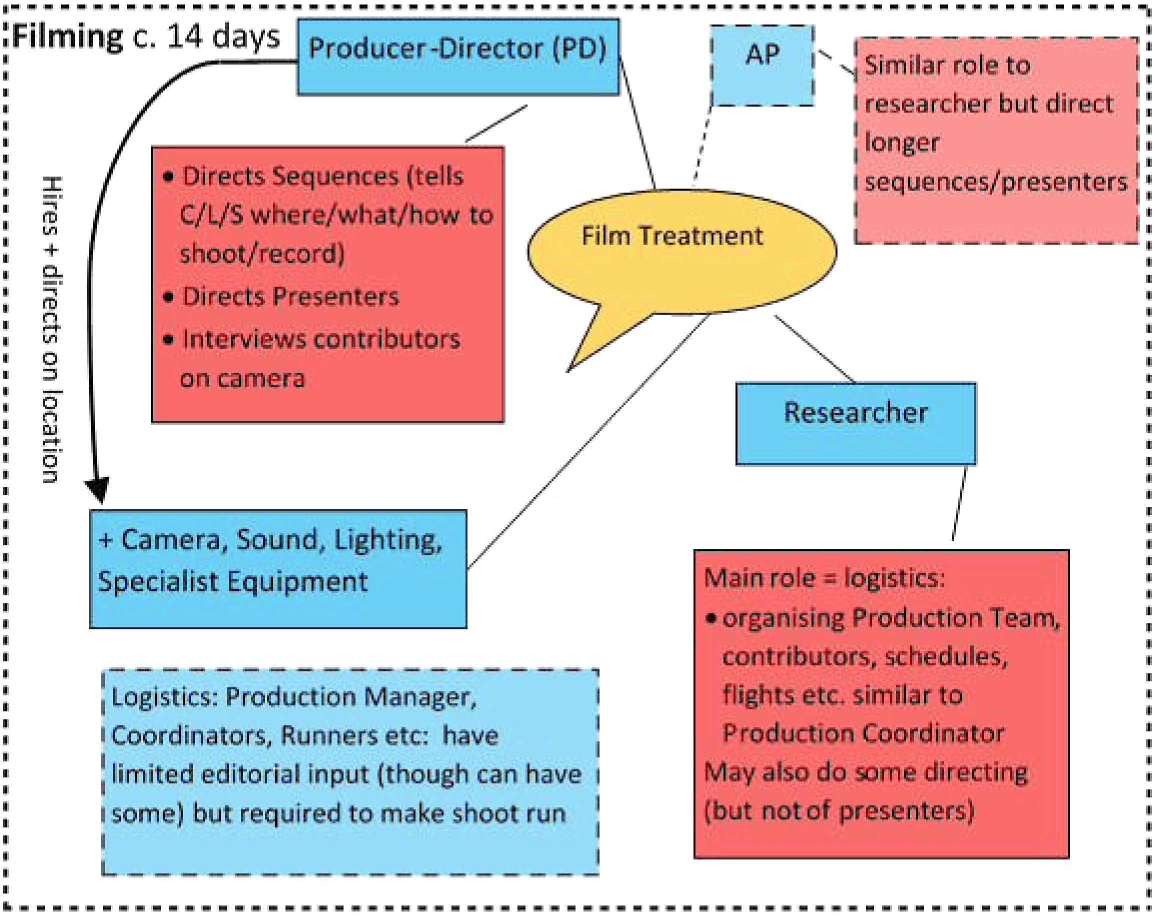


FIGURE 3

Capturing the material for an hour long science programme is usually achieved in twelve to fourteen full days of filming. This relatively short time period for filming is primarily the result of budget constraints, as filming is the most expensive part of the production process. A location shoot for a science documentary will include at a minimum the PD, researcher, cameraman and sound-recordist. These latter personnel will require a variety of equipment to perform their role (camera, lighting, sound recording equipment). These personnel and their equipment all need to be transported to the location and paid for their time. Other personnel may also be included on more complex shoots, if allowed for by the budget. Fig. 3 visually represents the filming stage.

During filming the researcher has limited creative directorial input. They may make suggestions to the director and cameraman as to what to film and how to film it, but they will not generally direct any whole sequences, nor will they direct a presenter if one is employed. Most science films will employ a production manager, coordinator and runners to deal with the majority of the logistics, but on shooting days the researcher will take on some logistical responsibility. They may have to book flights to location, organise the production team (ensuring everyone required is in the right place at the right time with the right equipment), contact contributors (to remind them they are being filmed) or engage in any number of other activities to ensure the shoots run smoothly. The researcher may do some filming however, shooting additional footage which can be included in 'making of' style short films at the end of the main programme (this is increasingly common).

Filming requires the producer-director to utilise their directorial ability. The PD, in conjunction with a cameraman, sound recordist, lighting director will aim to film sequences based on the shooting script. This will involve shooting footage and recording sound of locations, contributors, presenters, pieces of scientific equipment and much more, most of which, regardless of the detail of the shooting script, will not find its way into the finished film.

The PD will interview contributors on camera. From prior research and telephone conversations the PD will have written into their shooting script an expectation of what the contributor will say, or a desire for the contributor to say something very specific, and will lead the conversation in that direction (often until very specific phrases or words have been repeated). The PD will want contributors to look unscripted and natural, but also clear, concise and engaging, an often difficult balance to strike. The PD's questions are normally removed during the edit to produce the 'talking head' effect prevalent in many science documentaries.

The PD will also direct the presenter or presenters if they are employed. This can involve more or less hands-on direction, depending on the director and presenter and the relationship between them. Some presenters use a detailed script which they memorise, others have less well defined notes around which they ad-lib. The details of this relationship will be negotiated before and during filming. Whatever the details, the PD will try to ensure that the presenter communicates the required information clearly and engagingly.

Sometimes things don't go to plan. Contributors won't say what is expected of them, the presenter can't get their point across, the weather may intervene or myriad other things may prevent the PD from 'getting the shots' they wanted. Sometimes the planned shots, when actually filmed, lack the expected visual impact or interest that is required. This is where the creative and aesthetic talents of the PD (in conjunction particularly with the cameraman) are of most value. Seeing with a 'photographer's eye' allows the PD and cameraman to capture images which satisfy aesthetic demands, images which are intended to move the film beyond the purely didactic and stimulate an emotional response in their viewer. Knowing what to film and how to film it to produce both informative, but above all visually arresting and affective images, is a vital skill of the producer-director.

Once the footage has been filmed, the rushes[23] are taken into post production, the most important phase of which is the edit.

[23] The industry term for the filmed material collected during filming. Historically this was on film or video-tape but is now generally stored in digital files

Post-Production

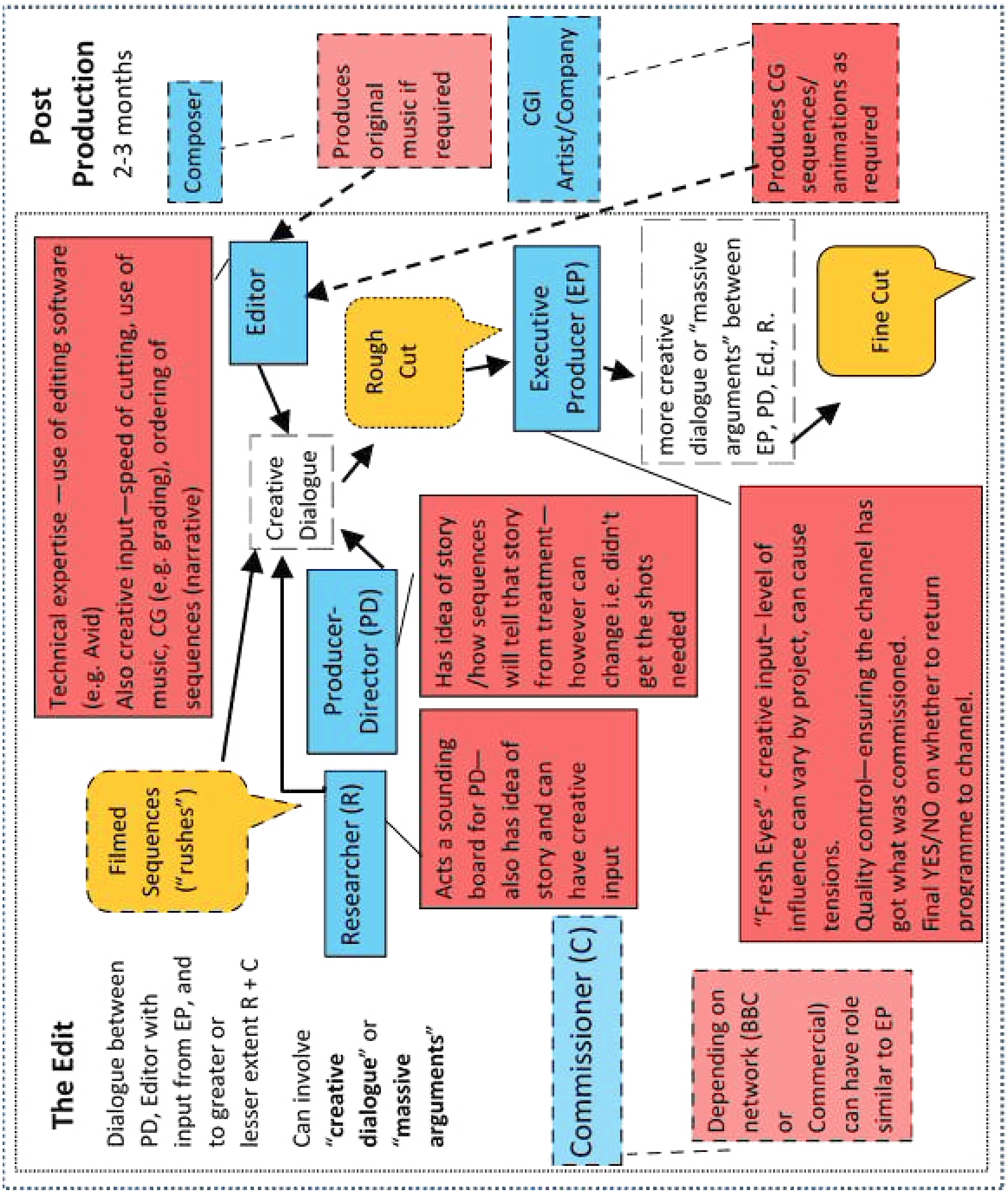


FIGURE 4

The edit is the place where the film really gets made. Though the other production phases are necessary, it is in the edit where the narrative of the film (its driving force, the thing which will keep its audience engaged) is honed. The PD, Editor, Researcher, Executive Producer, commissioner and channel controller interact during the edit and post-production to assemble and finalise the film ready for broadcast. These interactions can involve anything from 'creative dialogue' to, as one producer put it, 'massive arguments'. The Post-production phase is depicted in Fig. 4.

The physical editing of a film takes places in an edit suite. The edit suite contains the hardware; a computer with specialist keyboards, hi-resolution monitors and speakers, and editing software[24] the editor uses to deconstruct and piece together the desired footage from the rushes into a finished film. Editing a one-hour science programme normally takes 8-10 weeks. During the first month of this process, the producer-director and the editor are most heavily involved and will spend most of their time together. They will work long hours in close proximity, six or seven days a week. Due to this close proximity, the working relationship between the PD and editor is important. A healthy working relationship needs to be maintained if the film is to be completed. For this reason, PDs will often try to work with an editor they have worked with in the past. Building this rapport over a number of projects, understanding each other's working practices smooths the editing process considerably.

From their work in pre-production and filming the PD will have a reasonably good idea of the narrative structure and the specific information they wish the film, and each scene or sequence within it, to convey. However, what is possible to convey can (and often does) change during filming and when the filmed material is first reviewed in the edit. As well as a technical expertise in the use of specific hardware and software, the editor has a creative expertise in the detailed construction of filmic narrative. The creative dialogue between editor and PD in the edit ensures that an informative and compelling film is produced out of the mass of filmed material, a film that is in some way true to the imagined film conceived of in development, the pitch and as developed in pre-production and filming, but not enslaved to this image. Importantly, it is the responsibility of the editor to shape how the

[24] AVID Media Composer, Adobe Premiere Pro and Final Cut Pro are the most common editing programmes used by professional editors

overarching story and specific messages of the film are realised in the details of its construction.

The editor will influence the choice of which shots to use, in which order, the speed of cutting between shots, how and when to accompany these shots with graphic, music and sound, the overall ordering of shots in sequences, and sequences throughout the film. Whilst not attempting to actively misrepresent the scientific content, choices will be made which provide the film with greater clarity, greater narrative drive and greater emotional appeal. The intent will be to create a particular impression in the audience of the film. Nothing will be random, and nothing left to chance. The extent to which the editor is responsible solely for these different elements of filmic construction depend upon the working relationship between the editor and PD, and the PD's willingness to be involved in these detailed decisions. The editor will always concern themselves with the most detailed of these considerations, the PD may not. Through this work the editor (and PD) construct the building blocks of the film, weaving together visual, soundtrack and music into scenes, sequences and eventually the entire film, all with a particular intention and for a particular effect.

During the edit, the researcher will also have some involvement. Though they may offer some creative suggestions, their main task is to ensure that the film presents the scientific content accurately. As they have done the bulk of the research, the researcher is most knowledgeable about the science. However, as the most junior person involved in the edit, their suggestions can be taken lightly. As the focus is on creating as engaging a film as possible, accuracy is weighed against narrative or emotionally engaging content. It is extremely rare (though not unheard of) that scientific content will be actively misrepresented, but detail may be elided, caveats removed if it is decided that this makes for a more compelling or engaging film.

Any original music that is used requires the input of a composer. Computer generated imagery (CGI) or 'graphics' to use the industry term, require outsourcing to animation specialists. These will be arranged for and included in the film as the edit progresses.

After the initial 4 weeks or so of editing, a 'rough cut' of the film is assembled and shown to the executive producer[25]. Viewing the rough cut, the executive producer acts as a 'fresh pair of eyes'. Working so closely on a film can mean that the PD and editor become lost in the detail and lose sight of the bigger picture of the film. The rough cut viewing allows the EP to ensure that the film has a clear, overarching structure and is visually compelling. The EP also acts as a form of quality control. They assess if the film resembles closely enough the pitched idea to warrant returning to the channel. The EP will often make suggestions as to how the film can be improved or brought into line with its imagined appearance in the pitch. This may involve re-ordering sequences, adding or removing scenes or any other changes which (they believe) will improve the film, making it clearer, more compelling and more engaging for an audience. The EP also assesses whether or not the film is on track to be completed on time, assessing (and occasionally, if things are not progressing smoothly, mediating) the working relationship between the PD and editor.

This interaction between EP, PD, and Editor (and researcher) is often where creative dialogue can become "massive arguments", depending on the different and (occasionally) conflicting aims for the film. In drastic situations this can lead to a new editor or producer (sometimes called an edit producer) being employed to ensure the film gets made (usually to satisfy the demands of the executive producer).

Depending on their interpretation of the progress of the film, the EP will be more or less involved from the time the rough cut is viewed until the edit is completed. If they feel the film is faltering they may assess progress through

[25] Occasionally a commissioner will play a similar role to an EP during this phase of the edit. This generally occurs outside the BBC.

weekly (or more frequent) viewings. In extreme cases the EP may take personal control of editing the film.

If the EP judges that things are running smoothly they will allow the PD and editor to complete the film with minimal intervention. The PD and editor will finely polish visual, sound and musical elements of the sequences, hone the voiceover script and once this is completed have it recorded by a voiceover artist. This is usually one of the final tasks as the voiceover script will undergo multiple revisions to ensure it aligns with the timing and ordering of the film's sequences and is as clear, concise and informative as possible. Once the sequences are in place the sound and visuals are subjected to various technical procedures to ensure they are of the required quality for broadcast on network television. As this process is nearing completion the EP will view a 'fine cut' of the film, suggest any minor changes or approve the film as is, producing the final cut.

The final cut is returned to the channel controller and commissioner. They will view the programme and decide whether to broadcast it or not. In practise, programmes that reach this stage are almost always broadcast. In some rare cases the channel controller and commissioner may, however, request re-editing. This can represent a failure on the part of the EP, who is meant to ensure that the channel controller and commissioner are presented with the programme that they were expecting when they commissioned it, and that it is of the required quality. However, once the programme has reached this stage, has had this amount of time and money spent on it, it is extremely rare that it will not be broadcast in some form, even if this is after extensive re-editing.

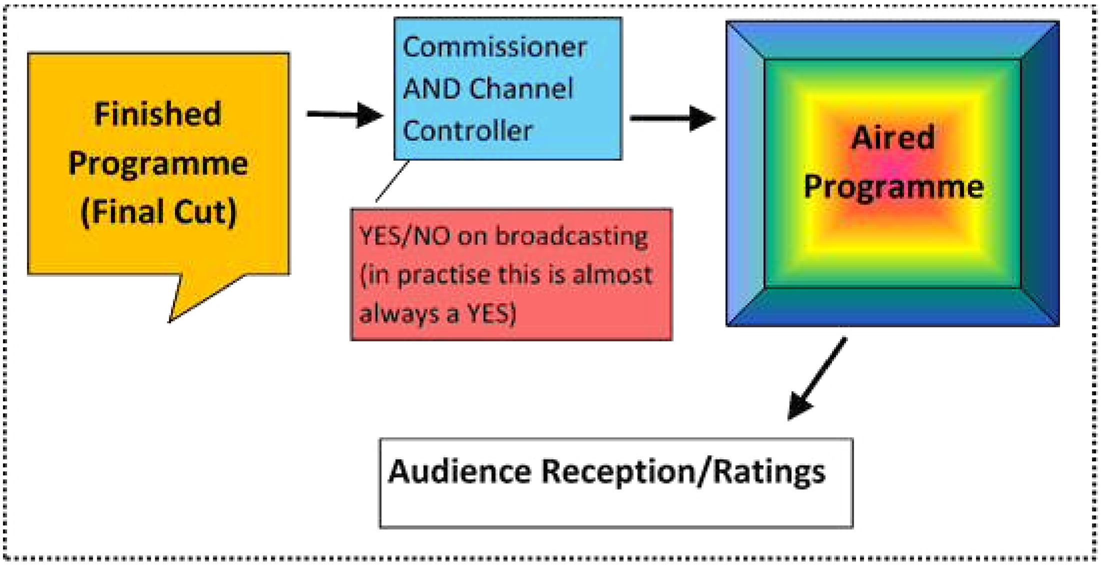


FIGURE 5

Post-broadcast, the 'overnights' are consulted. The overnights provide the programmes ratings and its AI score. The ratings indicate the size of the programmes audience. The AI, or Audience Appreciation Index, shows how highly the audience rated the quality of the programme, on a scale of 1-100. In comparison with other genres science programmes are not expected to receive high ratings. Depending on channel and time slot, BBC science programmes are expected to achieve between half-a-million and two-and-a-half million viewers. Commercial broadcasters expect smaller audiences. Programmes with three million or more viewers are deemed very successful. Science programmes are generally expected to achieve good AI scores, of around or above 84. Programmes with AI scores in the 90s are deemed very successful. Though ratings are comparatively low compared to other genres, they are still the primary metric for the success of a programme. A programme can be deemed successful if it has lower than expected ratings and a very high AI score, but programme makers' primary aim is high ratings. Fig. 5 represents the final phases of production, including the commissioner/controller sign-off, broadcast and analysis of audience response to the programme.

The overnights are hugely influential in the development of future programmes. Successful programmes will be emulated whether that be in format, style or topic. Topics, formats or style which did not rate well will be avoided in the development of future programmes.

Conclusions

In this brief sketch of the making of a non-fiction science programme some of the important elements that I will come onto discuss in the next two chapters have been hinted at.

The tension between accuracy of scientific content and televisual appeal are present throughout the entire process of production. Science film-makers must be accurate in their representation of and avoid misrepresenting scientific information, yet they must also appeal to a mass audience.

How a programme maker balances these competing demands is impacted by the specific audience they are tasked with engaging. Different channels and time slots bring different audiences, who can be appealed to in different ways. The success or failure of a programme to engage its audience impacts on job security, so making successful (i.e. widely-watched) programmes is the primary aim of the science film-maker.

Understanding how the film-maker negotiates the sometimes opposed demands for accuracy and engagement within the institutional constraints of broadcast television is vital to understanding why science is differently represented in different television programmes. This will be the focus of the following chapter.

CHAPTER 5
"IT'S JUST TELLY, HUNG AROUND SCIENCE" THE WORLD OF SCIENCE TELEVISION: PROFESSIONAL, STRUCTURAL AND GENRE PRESSURES

How best to engage the specific imagined audience for a science programme is a fundamental concern of the science film-maker. However, the non-fiction science film-maker's pursuit of as large an audience as possible is complicated by the demand to faithfully represent scientific reality. The film-makers I spoke to produce 'specialist factual' programming. There is a responsibility felt within the film-making community to faithfully represent science in the programmes they make, a responsibility built on the film-maker's relationships with the scientific community and with their audience. Scientists contribute to science programmes, and audiences approach the representations provided by these programmes, from a position of trust in the film-makers' ability and willingness to faithfully represent scientific reality. Film-makers must negotiate these competing demands, making a programme that is as engaging as possible whilst grounding it in scientific reality.

Regardless of a film-maker's intention to faithfully represent science, any programme presents only a partial representation. It must be made from a particular perspective, in a particular televisual mode focusing on some aspects of the reality rather than others. This is the nature of the televisual medium, which requires the compression and condensing of the vastness and complexity of any given reality into a form and format that fits within an hour or half-hour length broadcast slot.

There are a number of filmic techniques that can be employed to faithfully represent the real world and a number of aspects of any reality which can be faithfully represented. Non-fiction science film-makers represent specific aspects of scientific reality using particular filmic techniques to convince an audience the representation is true-to-life. The aspects of science that are represented, and the techniques used to achieve a true-to-life representation, are those which maximise a programme's potential to engage an audience within the structural constraints of television, specifically broadcast channel and time-slot. Film-makers employ different techniques to engage the audiences of different channels and time slots. The techniques of engagement which are used in a given programme impact which aspects of scientific reality the programme faithfully represents.

Non-fiction science programmes do more than just engage an audience. Science film-makers believe that their programmes affect their audience's relationship with science. Which aspects of science are focused on, and the representational devices used within the film will affect how scientific reality is perceived by an audience. Science film-makers do not believe their films will have much of an effect on their audience's scientific knowledge. They do however, believe that their films can shape audiences attitudes towards science, and overwhelmingly, it is a positive attitude towards science that they wish to promote through their films.

In what follows I will discuss:

- The tension between faithfulness to reality and entertainment in non-fiction science programme making
- The professional and institutional constraints which necessitate the negotiation of this tension, most pressingly, the need to satisfy as large an audience as possible
- How non-fiction science film-makers negotiate the tension between faithfulness to reality and entertainment
    - What counts as a faithful representation of science for a film-maker, and which aspects of science require less faithful representation.

- The techniques employed by science filmmakers to engage their audience.
- The techniques film-makers employ to both faithfully represent scientific reality and convince their audiences that these representations are faithful.

- The model of science film-makers work with which allows them to produce both engaging and faithful representations of science.
- What film-makers believe to be the purpose of non-fiction science television

Accuracy and Engagement: Internal Tensions in the Production Hierarchy

> Producer-Director B: "You can't play fast and loose with the facts"
>
> Producer-Director C: "I hate if I get something wrong, and it does happen occasionally, you know you just feel awful that you've got something wrong and also there's cases where something has been caught at the last minute and you just think oooh that was a narrow escape"
>
> Executive Producer E: "We never set out to get it wrong, obviously, but what you do set out to do is make it as entertaining as possible"

Accuracy and engagement are not always diametrically opposed. However, they can come into conflict with one another. This conflict is often negotiated most explicitly between different roles in the production process, with those more junior more concerned with accuracy and those more senior more concerned with engagement. However, even those members concerned with accuracy recognise the necessity of producing an engaging film.

Accuracy of representation is a more pressing concern for the less senior members of the production team, the researcher and producer-director (PD), for a number of reasons.

> Producer-Director G: "Scientific content you almost, not take that for granted but the basics of it you rely on your researcher to get that right"

For the researcher ensuring the accuracy of the scientific content of a film is the primary responsibility of the role. They are employed to know about the science, and to ensure that scientific content is accurate in a film. The producer-director is also concerned with accuracy of representation, for their own sake, for the sake of their audience and the sake of the scientists who contribute to their films.

Inaccuracies in a film have a variety of consequences, of varying significance. Some inaccuracies are entirely ignored, both by the film-maker and the audience. These inaccuracies will be discussed in more detail below. Those inaccuracies that are recognised can lead to complaints from knowledgeable audience members. This can require a response from the film-maker, which takes time and effort. This is one reason film-makers will try and avoid obvious inaccuracies.

More importantly, PD's are committed to accurately representing science in non-fiction science programmes because these programmes are expressly non-fiction. There is a perception amongst PDs that the audience will take what is presented to them in a science programme seriously. They will assume that it is factually accurate because the explicit and implicit signals in the programme indicate that it is a faithful representation of reality.

> Producer-Director B: "Different genres work differently, so if you're doing *Location, Location, Location*, or you're doing a Gok Wan show about fashion, or you're doing anything that's lifestyle orientated or any of these softer genres, pretty much you can over emphasise, you can change things around to fit the facts…from my point of view, we're not making a Gok Wan show about fashion, people are watching this and believing its fact because we're presenting it as a science show, so if it's a lie then that for me, ethically, sits really badly and I really struggle with that"

Other factors also influence PD's desire for their programmes to faithfully represent science. During the making of a film relationships with contributing scientists are established. These can be reinforced over a film-making career, as producers build up a list of contacts within the scientific community who contribute in more or less obvious ways to a number of films. This is particularly the case with scientist-presenters, who directors will often work with on a number of films. Allowing a colleague in front of the camera to get it wrong can have negative repercussions for the presenter and PDs can feel a responsibility to ensure this does not occur;

> Producer-Director C: "A lot of my friends are presenters, they just say 'you're putting words in my mouth and I have to stand by those for the rest of my life and if you make me say something that's wrong it's not you that people come back to!' And I always feel like it's me if I get it wrong, and they go 'yes, but it's not, it's me!' So yeah you do feel that responsibility. If I had David Attenborough say something wrong, I mean god forbid"

Even with one-off contributions from scientists to a programme, producer-directors can often feel a duty to their contributors. The relationship between producer-director and contributor is built on a mutual trust. Film-makers trust that the scientists will provide them with accurate and interesting information. Scientists trust that film-makers will not entirely misrepresent them. For this reason, producer-directors are often very concerned with ensuring that the scientists who contribute to their films are accurately represented.

Failing to represent accurately a scientist's contribution has a number of consequences. It means there are factual inaccuracies in their programmes, which is a problem for the audience who may believe the inaccurate fact is true. Misrepresentation also means that trust between the scientist and film-maker has been violated. On a personal level this can be difficult to manage. There are also professional consequences for the film-maker and scientist. Misrepresentation can mean a scientist's relationship with their peers is negatively impacted. The consequence for the film-maker is that the possibility of maintaining a future working relationship with a scientist can be jeopardised, a potential problem for the PD in their future film-making.

> Producer-Director B: "I will never be able to speak to that civil engineer again because the two hour interview he gave with [the monument] in the background which contained all the facts, he gave me the whole story, all his bits where he said it was only gonna crack by an inch but it's still a big deal, chopped out"

Total accuracy of representation becomes less of a concern as individuals move up the hierarchy of television production. The shift of focus away from accuracy occurs in part because executive producers perceive the impact of non-fiction science programmes on audiences differently and have a different, more distant, relationship with the scientific content of a programme, be that the scientists who contribute or the information sourced from journals. As a result, the executive producer, or those more senior (commissioner, channel controller) are more concerned with the potential for the film to engage with an audience.

Executive producers are involved in the early and latter stages of production. Pre-production and filming (the middle stages of production) are the phases where the PD and researcher will interact with scientists personally, and executive producers are generally not involved here. Of course, the majority of executive producers will have spent time as PDs, during which time they will have built relationships of their own with contributing scientists. However, on the films they later executive produce, executive producers will not develop working relationships with those specific contributing members of the scientific community. The role does not generally facilitate the kind of interaction required to establish personal working relationships with scientists who appear in the films they executive produce, so commitments they may have felt earlier in their career as PDs will be less influential. The mutual benefits of faithful representation apparent in the relationship between PD and contributor have less influence on the executive producer.

More influential in the executive producer's commitment to engagement rather than accuracy is their understanding of the relationship between a science film and its audience. Executive producers believe that the impact a science film has on an audience's understandings is limited. Executive producers generally think that television is a poor medium for providing information on a topic.

> Executive Producer F: "I don't believe I'm here to educate the audience, I think I'm here to interest the audience, I don't think the job of television is actually to educate people about the detailed minutiae and all the rest of it, they can go and find that"

> Senior Executive J: "Television is terrible for education, it's not like a book, you can't turn back the pages and check something again, there's no index, there's no cross-referencing anything like that…some people do get confused with the idea that television is somehow there to educate people in science, I don't think it really is, in the principles of science, yes, perhaps, but it's a terrible form for actually conveying information"

Ensuring total accuracy of all the scientific content of a programme is less important for EPs as they believe that the specific details of this content are unlikely to be picked up by the programmes audience. They are generally happy for scientific content to be omitted, simplified or glossed over in a programme. A minimum of detailed scientific content is acceptable, as an audience is unlikely to grasp more than this.

> Executive Producer H: "You're going to try and give them [the audience] maybe one or two nuggets of information that they could share down at the pub"

Rather than educating or informing people about science, non-fiction science television can instead hope to affect a shift in attitude towards the world. It can try and make people a bit more curious, inspire them to ask questions or look elsewhere (books, the internet, university courses) for detailed knowledge and understanding of science.

> Executive Producer F: "When I started I would have gone 'they [the audience] have got to know this information', and you

> think, do they really? The best I think you can truly hope for is to make people ask questions, to get them curious and interested in the world, not just about that subject, but just to broaden them in a way that makes them a bit more interested and curious about the world and ask questions of other things, that I would say would be all I I'd truly hope to achieve"

> Executive Producer H: "You can't hope to explain everything and you're much more trying to inspire people and get them to ask questions"

This quest to inspire an audience, and the belief in television's inability to effectively communicate detailed facts, explains the executive producer's concern with the entertainment potential rather than the detailed factual accuracy of a film. However accurate a film is, an audience will probably only understand a small portion of it and if a programme fails to engage an audience it will not be watched, rendering its accuracy moot. An engaging film, even if it is inaccurate, could inspire an audience, and the programme's inaccuracies will probably not be recognised by the audience as they are unlikely to absorb much of the film's content.

Though PDs may be more concerned with accuracy than EPs, this is not to say that PDs are unconcerned with engagement. Throughout the hierarchy of television production, it is understood that engaging an audience is the fundamental goal of a programme. Producer-directors may feel a greater sense of conflict compared to more senior production staff when accuracy is sacrificed to increase the engagement potential of a film. However, there is a broad acceptance from everyone involved in a production that a film must be engaging. Whether this is to ensure that a film does manage to impart some accurate scientific information, or because television is understood as primarily an entertainment medium, a programme must be made to attract and engage an audience.

> Producer-Director C: "I think the only way to educate is to entertain, so people won't be watching [a programme], but also they won't remember the information unless for some reason [the programme has] been engaging to them, so I think it can be perceived as a massive dichotomy between Strictly Come

> Dancing and a BBC 4 lecture, but actually it's all entertainment"
>
> Producer-Director B: "People come in after a long day at work and I think the days of wanting to be educated, that old kind of Reithian idea of educate, inform and' what's the other one?"
>
> WMW: "entertain?"
>
> Producer-Director B: "Yeah, educate, inform and entertain, I think we've kind of been left with entertain"

That engaging an audience is the overwhelming concern of science film-makers is exemplified by considering the responsibilities and status attached to the role of the researcher. The researcher gets the closest to the science during the production of a non-fiction science film. They are employed to know the most about the scientific information, and ensure the programme presents this information accurately. Even when sourcing scientific information, however, the researcher is subject to the demands to engage an audience.

In the early phases of development and scripting the researcher's primary responsibility is sourcing the programme's scientific content. Though the science content must be factually accurate, and the researcher must ensure that it is, scientific facts around which an engaging programme can be designed are actively sought out.

> Senior Executive N: "as a researcher you're having to find huge numbers of stories so your journalism is just driving the whole time, what's a good story? And you learn what a good story is very quickly on something like Tomorrows World"

The scientific content that is included in a television programme and subjected to the various televisual processes to maximise its engagement value in a programme is therefore scientific content that already has an increased potential to engage.

In the latter stages of production, most notably the edit, the researcher's input into the story is more limited. At this point, the researcher is primarily responsible for ensuring the facts are correct. However, the researcher is an entry level position in science TV. Their relative lack of seniority means their concerns are of the least importance. Though the researcher is the one most knowledgeable about the science content of the film, their input can be overridden by those in higher positions in the hierarchy who are more ostensibly focused on creating an engaging film.

> Producer-Director G: "So the researcher is there [in the edit], they can pitch in, they are kind of encouraged to be very vocal so in terms of keeping the accuracy on track, that's very much what they're kind of pricking their ears up to make sure no-one drags the story off in the wrong direction, they can be ignored, they often are ignored, rightly or wrongly"

Ensuring accuracy of scientific content is the primary responsibility of the most junior editorial member of the production team. More senior members are more concerned with producing engaging programmes, and can ignore the contributions of the researcher when editorial decisions are made. The desire to produce an engaging film can outweigh the desire to produce one which is entirely accurate.

Ratings

> Producer B: "If it doesn't do the numbers it will go and it won't come back"

Engaging an audience is a fundamental concern of science television makers because television is a medium dictated by ratings. The size of a programme's audience is the primary measure of its success. This is the case in both commercial and public television. Getting good ratings for a science programme in public television justifies the license fee, and meets the BBC's remit to ensure that as broad a section of the public as possible is presented with information about a wide range of subjects. In commercial television, good ratings satisfy advertisers and sponsors. On an individual level for the film-makers involved, a well-received film with good ratings helps to secure the next job and bolsters the reputations of those involved with the film. Films which do not rate as well as expected can jeopardise the careers of those who made them.

Though ratings are the most ubiquitous metric by which a programme's success is measured, different ratings are expected for different programmes. Non-fiction science television is a niche genre. 'Good ratings' for a non-fiction science show are generally significantly lower than for a primetime entertainment show, a drama or sporting event. Channels generally attract a different portion of the total television audience. Ratings for science programmes on a specific channel must align with the channel's overall audience share to be deemed successful[26].

Different channels not only attract audiences of varying sizes, the demographic make-up and perceived interest in non-fiction science programming is different on different channels. To achieve the required ratings, film-makers must appeal to the specific broadcast channel's audience. Different broadcast timeslots also bring with them audiences with different qualities. Science films are almost always designed to be broadcast in a 7pm, 8pm or 9pm slot. The broadcast timeslot alters the demographic make-up of the audience and the level of attention and interest that an audience can be expected to pay to a programme. From the early stages of production the film-maker will know on which channel a programme will be broadcast, and have an idea of their programme's broadcast time slot (though

[26] On British television there are a number of channels which regularly feature science programming. My interviewees suggested that BBC One, BBBC 2, BBC 4, Channel 4, The Discovery Channel and National Geographic Channel broadcast the majority of non-fiction science television in the UK. The expected audience for a science show on these channels is linked to the wider audience share they expect. BBC One generally commands the biggest audience share at any given time. Based on an average of figures quoted to me a BBC One science show could expect an audience of around 2.5-3 million – if it did not achieve this it would be not getting the ratings expected of it. A BBC 2 non-fiction science show may expect 1.5-2.5 million, larger than a Channel 4 programme which would expect 1-1.5 million. BBC 4 is available on free-to-air digital services such as Freeview or Freesat and expects much smaller audiences of between 500,000-1 million. National Geographic and Discovery are available through satellite or cable subscription services would expect smaller audiences than any of the non-subscription channels, normally less than 500,000.

this can change). Film-makers must satisfy the demands of the channel and timeslot audience in order to achieve good ratings.

Film-makers are aware of the expected quality (in terms of demographic make-up and levels of interest in science programming) of a channel and timeslot's audience. Film-makers attempt to produce programmes that will appeal to members of this audience and ensure that their programmes receive the ratings expected of a science programme on that specific channel at that specific time.

Channel Audience

Different channels have audiences with different characteristics. To ensure a programme rates well it must be designed to engage with the specific channel audience. The audiences for BBC One, Two, Four and National Geographic were described by my respondents. The film-makers I spoke to claimed that these different channels' audiences are appealed to by different programme styles or film-making techniques. One of the primary challenges for science programme-makers is ensuring their programme satisfies the demands of the broadcast channel audience.

The BBC One audience was described as the broadest, and as a result probably the least interested in science content. Many in the audience may be watching a science programme accidentally. A significant portion of the audience for a BBC One science programme may be a residual audience. A more popular programme may have been scheduled before the science programme, and some of the science programmes audience will be made up of people who have not switched channel at the end of the previous programme. Others in the audience may have switched to BBC One automatically, without the specific intention of watching a science programme. BBC One was understood by my respondents as the default viewing channel in many UK households. At any one time it commands a significant portion of the national audience (Statista 2016). This broad audience was described in metaphorical terms as 'sitting back'. The BBC One audience must be actively drawn into a science programme and engaged by a programme from a genre they normally would not be interested in.

The BBC Two audience was described as a mixture between the sitting backs of BBC One and some more 'sitting forwards' i.e. those people who may be more actively interested in science content in a television programme. The BBC Two audience is perceived as being generally more intellectual, and science programmes can address this by introducing more complex topics and lines of argument. This audience still contains elements who may be less interested and whose interest needs to be maintained however, so according to one respondent the challenge is to balance these different demands;

> Executive Producer F: "[on BBC two] you've got a core [audience] who are perhaps tuning in for a specific programme they want to find out about it, they're fine, but that means you can't patronise them, so you want to keep them, but you also need to make sure you're getting a broader engagement"

The BBC Four audience was described as being mostly comprised of people "sitting forwards". This much smaller but more engaged audience expects lots of science heavy content. They were described as desiring 'mind-fuck' science – this was often equated with topics relating to theoretical physics, cosmology or quantum science.

The National Geographic audience was described in gendered terms. The audience was painted as quite often being young and male. This perception impacts on various aspects of the programmes produced for the network, including the kinds of soundtrack, the pace of the editing and the language used by the presenters;

> Producer-Director B: "you're not gonna put out a National Geographic show which is like "and then there was a jolly big explosion and the boys ran away from the car and haven't they done very well", in a kind of BBC, or kind of quite mumsy, quite parochial, it's gonna be "awesome, duuude" it's gonna be all "gung ho, maaan!", and so right the way through from the pitch document that sold the programme, through to the scripting, through to the things the presenter says, to the ways its cut and the pace its cut, and the music soundtrack, and the music

> soundtracks not gonna be classical is it, cos the audience don't listen to classical it's gonna be rock, so yeah you're thinking of the audience the whole time"

Though these different audiences present specific challenges, the goal of the film-maker remains the same across all channels: achieving as large an audience as possible for the film. This is the primary purpose of any television programme. On a given channel, certain programme styles or filmic devices will be more appealing to the channels audience, and more likely therefore to help the programme achieve good ratings. Fast-pace editing, rock music and numerous Americanisms will engage a National Geographic audience, but will do little to keep the 'mind-fuck' science seeking BBC Four audience entertained. A the earliest stage of commissioning, the channel controller, commissioner and executive producer will attempt to make clear to the producer director the nature of the channel audience. The producer-director must factor this in to their programme-making. The perception of the broadcast channel audience constrains which representational devices or filmic techniques are used in a science programme.

Timeslot Audience

Non-fiction science television programmes are generally first broadcast[27] in one of three slots; 7pm, 8pm or 9pm. These slots increase in prestige as the evening progresses. The prestige attributed to a timeslot is related to the characteristics of the audience the slot attracts. Each broadcast timeslot brings with it an audience with a particular demographic, in a particular frame of mind and with a particular amount of attention it can pay to a programme. Programmes are therefore tailored to the characteristics of the different timeslot audiences. Programmes can be moved within the schedule once they have been made. However, due to the differing characteristics of the audience for each time-slot, and the work gone into catering to that

[27] First broadcast or first airing refers to the release of a newly made programme. Programmes when shown on repeat may be aired later or earlier in the daily schedule, but for a first airing 7-9pm are the prime slots.

audience, it is highly unlikely that a programme intended for 9pm broadcast will be moved to a 7pm slot, or vice versa (at least not without significant re-editing).

At 7pm it is assumed that the audience's attention can only be partially devoted towards their television. It is presumed that many audience members will be preparing or sitting down to their evening meal. They may be moving in and out of the living room, eating or conversing with family. This will, it is assumed, limit the attention they can pay to their television sets. If attention is divided between the television and other household activities, then the audience cannot be expected to follow an unbroken hour or half-hour length filmic story or argument. The ability to cover a topic in great depth is reduced as an audience cannot be guaranteed to engage with the whole programme. Programmes broadcast in this slot reflect this in a number of ways. Numerous entry points can be included throughout the programme, to reiterate or reintroduce ideas. 7pm programmes may consist of discrete self-contained elements that a viewer can pay more or less attention to as the programme progresses. These shorter elements provide limited depth or detail.

The 7pm slot exerts constraint on content as well as form. The presence of children in the audience, the fact that people may be eating, and the films pre-watershed slot, limits the topics that are likely to be approached, as well as the ways in which they are presented. As one respondent put it;

> Producer-Director B: "We know a lot of families are sitting down to watch it at 7 o'clock, you're not gonna have some massively technical thing on there that's not going to appeal to 12 year old kids because then their parents won't watch it, or similarly you're not gonna suddenly put on there something about the science of sex toys because, you know, again, family aren't gonna watch it"

The 8pm slot forms a bridge between 7pm and 9pm. The audience may at this point in their evening be putting children to bed, doing the washing up or be distracted in other ways so as to not yet be fully able to dedicate their attention to the TV. A more cohesive and coherent long-form argument or narrative can be utilised in the film-making at this time, but audiences are perceived as still requiring re-iterations and re-introductions throughout the programme to ensure they can follow the story or argument.

9pm is seen as the prime slot for specialist factual programming. The filmmakers believe that the audience at that time is most able to engage with their television sets. The distractions presented at 7pm and 8pm are generally less apparent and the filmmakers believe that the audience are ready to engage with a weighty topic or argument. A number of filmmakers used the image of audience members sitting down with a glass of wine ready, and willing, to watch the TV. 9pm, however, is also the prime slot for drama and other entertainment formats. Science programmes have to match up to these other genres in terms of their appeal. The audience are more prepared to be engaged, but are also more discerning.

Because the level of engagement and discernment is higher, filmmakers are able to, and must, tackle subjects in ways which are unavailable to them in the earlier slots. Filmmakers can approach a subject in greater depth and include more scientific content or detail. An overarching argument can be weaved through the film. The film can also utilise more complex narrative devices which cannot be implemented in the earlier slots. The 9pm science programme must also compare to 9pm dramas or sporting events in other ways. The visual elements must be as aesthetically appealing as these other genres, and as absorbing. A soundtrack that complements both the visuals and talk elements of the programme must also be included, to heighten the programmes appeal.

The structural pressures of broadcast television constrain the film-making process. If a programme is to achieve 'good ratings' (which it must be designed to do), the film-maker must recognise and work within these constraints. From the earliest stages of production the film-maker will know on which channel a programme will be broadcast. This channel's audience will have to be catered to, impacting the representational and communicational devices used in the programme. The time-slot will also most likely be known.

Time slot and channel will have an impact on the form of the programme and what techniques it uses to engage its audience. The form and techniques of engagement the programme uses to engage its audience will in turn impact the way in which the film-makers attempt to faithfully represent scientific reality, and which aspects of that reality they choose to faithfully represent.

The necessity of achieving an audience, and the perception that audiences for different channels and different timeslots can only be engaged in specific ways, means that when making a specific science programme for a specific channel and time, the representational options open to the film-maker are limited. The format that is selected to engage an audience will impact on how film-makers approach faithfully representing science. This means that across the television landscape a variety of representations of science are produced, precisely because different audiences are perceived as being engaged by different programme forms, and these programme forms shape how (and what aspects of) science is faithfully represented.

Catering to Different Audiences

> Senior Executive J: "If you just want to give them science then give up now, go and read a text book or whatever, that's not the job, that's not the world we're in"

Making the world of science engaging is the fundamental challenge of science film-making. It is a challenge that must be satisfactorily overcome in order for a science programme to be successful. However, this is a challenge that must be met whilst producing representations of science that are faithful to scientific reality. Different audiences, on different channels and at different times, are perceived as being best engaged in different ways. This means that different representations, which are both faithful and engaging must be produced.

In order to engage a 9pm audience, an hour length programme built around a complex yet coherent story or argument can be presented. In non-fiction science television, the documentary format is most often employed to do this. Documentaries adhere to a set of conventions which mean an audience reads them as faithfully representing the world. The specific documentary conventions that science film-makers adopt to convince an audience their representations are faithful are supplemented by narrative forms and devices borrowed from fiction to increase audience engagement.

> Executive Producer E: "It becomes most evident on long-form films… in an hour long film, even a half hour film, you've got a lot of time to play with, you can change the order around you can create longer scenes, shorter scenes, you can do all sorts of things with that, it's a really big canvas to draw on, and so you need to know something about storytelling"

Using fictional narrative devices, however, has an effect on faithful representations of the processes of science. Rather than providing faithful representation, science documentaries represent (or fail to represent) scientific processes in ways which serve the narrative of a film. Science facts can be represented more faithfully without hindering a film's narrative. Science facts are the pieces of information relating to some aspect of the natural or physical world produced by scientists, discussed at conferences and published in journals; the content of scientific discovery, rather than its context. It is possible to weave science facts, into a fictional narrative structure whilst preserving fidelity to the facts.

Shorter-form non-fiction science programmes cannot employ the same narrative complexity. The length of these programmes precludes overly complex narratives, and their scheduling (usually earlier in the evening, between 7-8pm) brings an audience that is not expected to pay attention to an overarching story. These programmes attempt to engage an audience in other ways. Borrowing from other genres will provide different methods for presenting science. Short-form programmes may employ more current affairs style communication, engaging an audience through the relevance or topicality of their content. Other formats such as chat-shows, or magazine programmes can be used to present science in an engaging way to an early evening audience. The focus remains engaging a perceived audience for the programme on a specific channel and at a specific time. However, the representational devices used in shorter-form programmes can reveal more of the processes or uncertainties of scientific reality, due in part to the relative absence of the need to conform to rigid narrative structure.

Science Documentary

Science and documentary have a long history. From its earliest inception, science has been an area of focus for the documentary maker (Boon 2008). In contemporary television, factual science programmes which are made for the 8pm and 9pm slots are most often documentary films (Van Dijck 2006). Film-makers attempt to convince audiences that their representations of scientific reality are faithful by utilising the documentary format. Documentaries are able to convince an audience that their representations are faithful because documentary is perceived as being demarcated from other genres by its relation to actual goings on in the historical world (Nichols 1991).

> "We expect to apply a distinct form of literalism (or realism) to documentary." (Nichols 1991, p. 5)

An audience expects a documentary to present a faithful representation of some aspect of reality. An audience recognises that what they are viewing is related to reality in this more direct way by the adherence of documentary films to particular filmic conventions.

> "The most fundamental difference between expectations prompted by narrative fiction and by documentary lies in the status of the text in relation to the historical world…cues within the text and assumptions based on past experience prompt us to infer that the images we see (and many of the sounds we hear) had their origin in the historical world…" (Nichols 1991 p. 25)

The specific conventions a documentary utilises to prompt its audience to understand it as a documentary vary between documentary sub-genres. The details of these different conventions will be provided below. Briefly, these conventions include specific methods for capturing sound and image and knitting them together in ways which audiences have learned to read as faithful and authentic representations of reality.

Documentary does not only represent reality, it has a point to make. Through its representations a documentary intends not only to inform its audience about some aspect of reality but to articulate an argument or further a specific point of view. A documentary may be designed to bring some disregarded aspect of reality to an audience's attention, to engender a new way of thinking about some aspect of reality or to re-examine or re-confirm established ideas through focus on a new application of these ideas in the real world. Whatever its specific intention, a documentary will be designed to convince an audience not only that its representation of the world is grounded in historical reality, but that this representation is in some way significant. Documentary not only represents, it makes representations in the rhetorical sense (Nichols 1991). In this way, documentary is designed to be taken seriously. It is made not only to convince its audience that its representation of the world is faithful, but to impact on how this aspect of the world is subsequently understood by its audience. Documentary's ability to shape understanding rests in its ability to be taken as a faithful representation of the world. When those conventions which convince an audience of the authenticity of representation are adhered to, documentary representations have the power to shape their audience's understanding of the world.

> "For a great many people, these images and these representations will be, if not the sum total of their knowledge, a dominating factor in awareness. Such representations actively construct a historical reality we may not otherwise see – cobbling much of it together from shards of myth and fact,

from the tissue of sometimes contradictory ideologies already circulating within the culture" (Nichols 1991, p. 12)

Though the above described some of the broad tendencies of the documentary genre, there is no single documentary mode. Documentary can employ different presentational forms to 'faithfully' represent reality, convince an audience this representation is faithful and shape an audience's understanding of the world. The following typology, drawing on Corner (1996, pp. 28-30) and presented in Table 11, identifies the different kinds of talk and image documentary can employ.

REPRESENTATIONAL MODES IN DOCUMENTARY	
Image	**Talk**
Reactive Observationalism (RO): Fly-on-the-wall style filming. It is an "indirect mode placing the viewer in the position of vicarious witness, requiring high level of interpretive work" (Corner 1996, p. 28). The image may be asked to speak for itself, without commentary or a presenter to direct audience interpretation. The images of the reactive observational mode therefore need to be inherently compelling and interpretable in order to maintain viewer interest.	**Overheard Exchange**: "This is the speech of observed subjects…the proximity of overhead speech to the coherence and pointedness of dramatic dialogue will vary as will speakers indications of self-consciousness and of performance" (Corner 1996, p. 29). This speech is not directed towards the camera (and thus the viewer). The audience overhears this kind of talk. The speech will be more or less directed by the film-maker (depending on the use of RO or PO). It requires interpretation to understand in what direction it is moving the argument or story of the film.
Proactive Observationalism (PO); similar to Reactive Observationalism, but with greater and more obvious directorial intervention in the pro-filmic through manipulation of mise-en-scene and montage. A more obviously constructed visual argument, created and defined by the film-maker, is employed; "The fundamental mode is still indirect but the depiction has been more heavily coded, perhaps more richly inflected" (Corner 1996, p. 28). This mode establishes a continuum, with the transparency of reactive observationalism at one end, and	**Testimony**: Interview speech. Can be used as direct address to the camera or in voiceover. It is more obviously *for* the audience, and serves a more obvious purpose; to explain, contextualise or drive the argument forward. The different ways testimony is used, and contextualised by the images which carry it, can emphasise its objectivity or subjectivity.

heavily directed modes such as dramatised reconstruction at the other.	
Illustrative: "Visualisation is subordinate to verbal discourses, acting in support of their propositions or arguments" (Corner 1996, p. 29). In the illustrative mode the visual narrative/argument is subordinate to the text (talk). The talk carries the argument and the images support the claims made.	**Exposition**: Voice of god commentary or Presenter direct address (piece to camera). Obviously directed at and *for* the audience. Can be more or less subjective but is generally and historically associated with objectivity.
Associative: "Here the visualisation is primarily engaged in the creation of second-order meanings, producing a kind of visual exposition or visual evaluation. This exploitation of the connotations and symbolic resonances generated by the pro-filmic, shot type and editing, …[can be used] for more directly referential purposes…Some uses of the associative may be primarily aesthetic rather than cognitive, aiming to produce a pleasing representation not necessarily one with increased informational yield" (Corner 1996, p. 29). In the associative mode the imagery is employed to connote wider congruent or dissonant themes or ideas presented in the talk, or to stimulate an emotional response alongside the cognitive response produced by talk. The associative relationship of image to talk can be more or less obvious.	

TABLE 11

There are four broadly identifiable sub-genres or modes of documentary; the expository, observational, reflexive and interactive[28] which employ these different presentational forms to a greater or lesser extent. The latter three, in different ways, stand in opposition to the former expository mode. Science television programmes when drawing on documentary conventions overwhelmingly utilise the expository mode (Van Dijck 2006). I will focus on

[28] For a thorough discussion of the reflexive and interactive modes see Chapter 2 of Nichols (1991).

describing some of the key characteristics of expository mode, and offer a contrast between it and the observational mode.

Expository Mode

> "The expository text addresses the viewer directly, with titles or voices that advance an argument about the historical world" (Nichols 1991, p. 34)

Expository documentary is the oldest and perhaps most recognisable documentary mode[29]. It is a mode defined by talk. The talk presents a case or argument, which is supported by the visual elements of the film. The most prevalent forms of talk are exposition and testimony; voice-of-god commentary, presenter direct address (or piece-to-camera) and interview talk. These forms of talk are authoritative, to be taken at face-value as faithful accounts of the world.

> "The expository mode emphasises the impression of objectivity and of well-substantiated judgement." (Nichols 1991, p. 35)

The pro-filmic (i.e. real-world) events are enrolled by the film-maker in order to support the case or argument put forward. Interview talk is shaped in line with the will of the filmmaker and used to support the over-arching argument the film as a whole develops. The visual elements of the film act to evidence the claims made in the talk. The images are predominantly illustrative and occasionally associative. In this way the expository genre deals in the more abstract or general. Particular pro-filmic events are used to illustrate more general trends or overarching ideas.

> "This mode supports the impulse toward generalisation handsomely since the voiceover commentary can readily

[29] This mode developed in the early 1930s, and is particularly associated with the film-maker John Grierson. See e.g. (Boon 2008) for a thorough history of documentary films.

> extrapolate from the particular instances offered on the image track" (Nichols 1991, p. 35)

The expository genre generally speaks to its audience from within an accepted framework of ideas. It reinforces this framework through the appeals to authority made by its presentational forms. Things are accepted as being the way they are represented in the expository documentary because the expository documentary employs the authoritative devices described above.

> "A topical issue can be addressed within a frame of reference that need not be questioned or established but simply taken for granted" (Nichols 1991, p. 35)

In an expository documentary the sound-track will drive the story or argument of the film forward through voice of god commentary and selected parts of expository interviews. The images of a documentary will primarily (but not solely) provide visual evidence to support the claims made by the soundtrack (Nichols 1991). Its content will generally act to reinforce pre-conceived frames of references or understandings of the world.

Observational Mode

Fly-on-the-wall documentaries are designed to place the audience in the position of vicarious witness to an event, an event depicted 'transparently' in the film. The intervention of the film-maker, and the camera itself, are intended to be invisible[30]. The fly on the wall documentary, which utilises Corner's (1996) reactive observational mode in its imagery, is "dependent on the comprehensibility, interest and visual 'strength' of the pro-filmic events themselves". As a result, this style documents places that seemingly have

[30] Though the intervention of the film-maker is disguised, these films still construct and present a particular representation of reality. Though the action in front of the camera may have occurred without direction from the film-maker, what appears in the final film after it is edited is at the film-makers discretion. The story constructed in the edit will generally highlight the extraordinary goings on and define the people who appear in the film in simple terms.

some inherent drama to them; hospitals, schools; the emergency services. The pro-filmic world is populated with people in situations where daily life itself provides the drama. These programmes are often very popular, as attested to by the success of shows such as *One Born Every Minute*, *24 hours in A&E*, *Educating Yorkshire/Essex/Cardiff* (BARB 2013). Where the world itself lacks drama, the individuals who populate the world are often larger than life 'characters' who are engaging in their own right[31]. Therefore, if the film-maker believes the pro-filmic events are not easily understandable or compelling they will avoid this using this mode.

Documentary Modes and Science

Science documentaries are made almost exclusively in the expository mode (Van Dijck 2006). The talk they employ is testimony and exposition. Overheard exchanges between scientists which an audience have to make sense of are almost never presented. The interpretive work of the audience is kept to a minimum. Presentation in the form of interview testimony, the presenter's direct address or voice-of-god commentary renders the talk of a science documentary unambiguous.

Science programmes employ the latter three visual modes outlined above to varying degrees. Proactive observationalism is sometimes used. The audience of a science programme can be presented with shots of scientists at work in labs or at field sites. This work is directed in particular ways. Various cuts and close-ups are used to illustrate or emphasise particular aspects of scientific work. Capturing this footage will have interrupted the actual work of the scientists in ways which reactive observationalism will not have.

Image is predominantly used illustratively in service of the talk, to support arguments and present visual representation of ideas offered in the talk. This can be achieved through filming experimental processes, scientific equipment or specifically designed props or models. For more abstract concepts, or for

[31] The BBC obs-doc *The Call Centre* focused on the work of a Swansea call centre. The boss, Nev Wilshere, quickly became the focus of the programme for his "larger-than-life" antics.

things which are too large or too small to easily film (atoms, galaxies) computer generated imagery (CGI) or graphics are often used.

Imagery that is illustrative will also inevitably carry associative meaning. The precise choice of what to film, from what angle with what lighting, accompanied by what soundtrack and how to locate these different shots in sequences within the film, will conjure particular interpretations in its audience. The scientist speaking to the camera from behind his imposing desk in his well-appointed office overlays a visual connotation onto the scientist's talk. The authority of the scientists and the institution of science is reinforced in this visual configuration. With the speculative use of CGI to illustrate an idea that is beyond the scope of human witnessing, aesthetic concerns will sit alongside illustrative ones.

These different modes of talk and imagery will be utilised in the majority of long-form science programmes. It is much rarer to see science represented using more observational modes. According to the film-makers I spoke to the world of science is niche, boring, and complicated. The pro-filmic events of science are unsuited to the observational mode. The actions of scientists going on in their daily work are difficult to interpret in meaningful ways for an audience without the guidance of expository commentary or testimony. The lab or field-site is an unfamiliar place for most non-scientists. The actions of scientists within these environments, their skilled use of various pieces of equipment, and specialised (linguistic) interactions with other scientists are difficult to make sense of for the non-specialist audience member without the talk to guide them.

Even if it were interpretable, in the view of science film-makers, the world of science contains less inherent compelling televisual drama than a school, hospital or other emergency services. A police chase, the work of a midwife or the trials and tribulations of the classroom are viewed as inherently more engaging than lab work. Individual scientists are unlikely to engage the audience of an observational film by virtue of their inherent charisma. According to my respondents, scientists are mostly awkward, non-telegenic individuals who an audience will not care about. This persuades film-makers that representing science using the observational mode is not appropriate. A faithful representation of science may be constructed using the observational mode, but film-makers believe it will not be compelling.

These different evidential modes have a different relationship to truth. The truth of reactive observation and the overheard exchange is seemingly more transparent. The observational mode's representations appear to provide a more immediate, unmediated window on reality, a reality the viewer would have borne witness to if s/he were in the position of the film-maker and which s/he vicariously witnesses through their film. The observational documentary claims to know, and show, what went on in a specific part of the world at a specific time and place, and its relationship to truth is built on this claim.

The truth of the expository mode appears as a more objective, general, over-arching truth. The expository mode uses the specifics of what is uttered and captured on film, but demonstrating the connection between what is said and filmed and the specific time, place and location where this occurred is not its concern. The speech content is used to inform the viewer of wider or more fundamental beliefs, ideas or facts and compels the viewer to understand these beliefs, ideas or facts in a way which aligns with their framing in the documentary. The expository documentary claims its truth from the content of what is said, rather than its saying (Corner 1996).

In long-form programmes, science could be represented using reactive observational visual modes and overheard exchanges. However, it almost never is[32]. An audience for a long-form science programme almost never sees the day-to-day goings on in the world of science. The day-to-day work of science thus appears unimportant in the reality of science. Long-form science documentaries represent science in ways which abstract it away from the day-to-day and into the realms of more abstract truth. The taken-for-granted

[32] More recent, experimental films e.g. *Hopeful Monsters* attempt to more away from the traditional expository mode towards more observational and reflexive documentary practises. This film will be discussed in more detail in Chapter 8.

assumptions about the reality of science, its relationship to fundamental truth, is reinforced through this expository mode.

What this also means is that film-makers must utilise other techniques to make their expository documentaries engaging for an audience. The expositional talk and illustrative images will help to convince the audience that what they are watching is a faithful representation. The scientific content communicated by this talk and these images will engage some audience members. However, film-makers believe that a programme requires more than faithful exposition of content to engage the broadest possible audience. The images of a long-form science documentary must do more than just illustrate. Competing with other high-budget programmes in the schedule, a science documentary must look the part. Its images must have an aesthetic appeal that attract an audience, and within its members stimulate an emotional response. Just as importantly, a science film must tell a good story.

> Executive Producer F: "It's teasing out the story and telling it in a way that is appealing to people's story telling instincts as opposed to their cerebral 'that's fascinating tell me more', that's a very narrow audience, a broader audience will want that but dressed up in a way that's much more the way that most humans engage, which is storytelling"

Engaging the Documentary Audience: Telling Stories

> Executive Producer F: "It's all very well having the information but how are you going to tell the story?"

Constructing a compelling story (both in the talk and visuals of a programme) is an essential skill for the science filmmaker involved in long-form documentary production. The pressure to think in terms of the narrative of a programme is felt throughout the hierarchy of production and at all stages of the making of a programme. This is indicated when the accounts provided by respondents from different levels of the organisational hierarchy of television are compared. Throughout this hierarchy, individuals claimed that a large part of their editorial responsibility (if not their primary purpose) was to focus on the story or narrative elements of a programme. Making sure the facts were exactly correct was painted as the responsibility of someone else.

> Executive Producer E: "So I spend quite a bit of time trying to, with teams, who are more experienced or less experienced, not trying to teach them really, but just sort of nudge them, encourage them and talk through what they've done and how it might be done differently…and so you spend a lot of time, both in the pre-scripting stage and in the scripting stage, and then in the edits, working on story"

> Editor O: "Most people would agree that in science documentary film-making, particularly executive producers and beyond but generally in the culture, people believe that the information is of premium importance and that would be the content, that facts, the scientific delivery of the information, and I think what you've got to do as an editor is obviously you've got to include that, you've gotta make sure that it's right, but the primary role becomes giving that story an emotional backbone, and that's partly music, that's partly story-telling, its partly giving it a narrative. You might unpack a story in a mysterious way, you might hold back information to reveal it later, you might tell a story and you might go back to the past of how it came to be, or the history of it, very late on rather than telling it in a purely chronological sense that might just be less interesting, it might be more exciting to hear that information late on, when you know the current situation, but whatever you do you're trying to create an emotional feeling, so when I take a scene and I've got a grasp from the producer of what that scene is about, and the information that's necessary to say in that, I'll think of an emotional, interesting way of starting it and taking it from there on"

> Producer-Director G: "So that's what a director's doing, thinking about all those extra things on top of the scientific content, scientific content you almost not take that for granted but you, the basics of it you rely on your researcher to get that right and the nuance of it, that's your job to bring out the relevance of certain aspects of the science or to focus on how things might be relevant to society or how the contradictions within a scientific community, how those are playing out, things like that, so the subtleties, that's the kind of thing that you tend to focus on as a director…so there are lots of parts of the job that have got very little to do with science"

> Senior Executive K: "Part of my day is dealing with on-going productions which I'm in charge of that I look after and I guide them in terms of where they're at with their editorial, what they're doing, where they're filming, mainly around the storytelling, how do we get over particular conundrums and any problems they're having"

The above attests to the status of narrative in long-form science film-making. Individuals from different levels of the hierarchy of production all believe the onus is on them to ensure the emotional or narrative elements of the film are included, and that others in the process are more interested in getting the facts right.

For the science film-making community faithful representation of science is important, but it is not sufficient for a film to be successful. The narrative of a film, and the emotional responses it is designed to engender, are required in order for a long-form documentary film to successfully engage its audience. Science film-makers therefore shape their representations of science around particular narrative structures, characteristics of which have implications for which aspects of science are faithfully represented.

Long-form Engagement: Narrative Forms

> Executive Producer E: "In science you can tell stories, and by that I mean stories in the way Hollywood deals with them, stories that have a beginning, middle and end, stories where you manipulate the flow of information deliberately to create emotional highs and lows"

Long-form science film-makers shape scientific content into narrative structures familiar from other genres to add emotional interest, tension and drama. These narrative forms are used for dramatic effect and added entertainment value, with the intent to sustain an audience's interest over the course of a long-form programme.

> Executive Producer F: "We use all the devices, I would say that a drama or book or novelist uses, which is storytelling, is revealing things, teasing things to sort of like keep people

> threading through and keep them ‘What happened? What happened? What happened?’,

This storytelling craft is seen as vital for engaging and maintaining an audience. Scientific information presented without these narrative devices is niche in its appeal, complicated, distant and boring. These qualities are all anathema to a television audience. To appeal to a TV audience science content has to be clarified and packaged in a neat story.

> EP KB: “In science [TV] you have to craft a story that may not, a narrative that may not naturally be there”

> Executive Producer F: “Science documentary has that problem that there isn’t necessarily a natural narrative, you have to find it, you have to engineer one so you’re constructing a narrative. History has a story, it has a narrative, so it’s a question of how am I going to tell this rather than what the hell is the story?...That’s the tension, that is the most difficult thing as a producer to produce science television is trying to engineer or construct a story where there isn’t an easy way through.”

To tell the story of science, film-makers use a number of narrative techniques. They may simplify complex scientific processes or debates or exclude them altogether if they over-complicate the story. Film-makers may alter timeframes or withhold information to heighten the narrative tension of a programme. In so doing, these aspects of scientific reality are not faithfully represented.

Using narratives that have a “beginning, middle and end” renders the faithful representation of the processual aspect of scientific reality difficult. The scientific process is open-ended and processual. Science as an endeavour periodically provides new understandings of the world but these understandings are always open to further scrutiny and re-development (or at least, the scientific community aspires to this kind of open-endedness). To create engaging programmes, the open-ended, non-algorithmic reality of science becomes subject to a narrative rationale that demands closure, finality and the definite.

Long-form Engagement: Imagery

Alongside narrative, long-form documentaries also appeal to an audience through their use of compelling visual imagery. As 9pm long-form documentaries are the most prestigious non-fiction science programmes, their visual imagery is the most carefully crafted. 9pm science programmes are broadcast alongside other high-budget, high-prestige programmes in the schedule. They therefore require the same production values as these programmes if they are to appeal to a 9pm audience. The quality of a film's images can be decisive in attracting an audience. A science programme can appeal to an audience, regardless of their interest in science, if the visuals are compelling enough.

> Producer-Director C: "you wouldn't watch it if it looks crap, and if you're not interested you won't watch, if it looks beautiful and you're not interested you might at least [watch the programme]"

The imagery of a long-form science film, amongst other things to be discussed, is designed to hold an audience attention through is innate aesthetic qualities. Through their aesthetic appeal, the images of a film stimulate an emotional response different from the more cognitive or intellectual response to scientific content, or to the storytelling instinct described above. Inspiring this emotional response is an important way in which science film-makers hope to engage their audience.

> Editor O: "In any form of film-making the emotional delivery is of most interest, people connect with emotions and that's human stories and that's faces and eyes and things that give them a feeling, the information and the continuity in the material and various other things are of less importance"

Silverstone (1985) also suggests that the images of a documentary film serve this purpose;

> "Images if they are to be anything other than wallpaper, will consistently push the film towards the other pole of narrative

structure – to story and to myth, to the power and attraction of emotions" (Silverstone 1985, p. 173)

Long-form Representations of Scientific Reality

The seemingly faithful representation of science presented in the long-form documentary is shaped by the expositional documentary mode adopted and the visual and storytelling techniques film-makers employ to make these programmes engaging. This mode and these techniques define which aspects of scientific reality film-makers consider worthy of representing.

To satisfy both the aspiration to faithfully represent science and the demand to produce an engaging film, long-form science film-makers must have a perception of scientific reality which allows them to produce what they believe to be faithful representations of some aspects of that reality whilst utilising techniques of engagement in their representations which distort other aspects of this scientific reality.

The specific aspects of scientific reality film-makers represent are those that make the work of making a film engaging as simple as possible. For science film-makers, this means representing scientific facts faithfully, whilst producing distorted representation of the scientific process to further the engagement potential of a film.

Getting the Facts Right

For the science film-makers I spoke to, faithfully representing science means above all faithfully representing the knowledge produced by science; scientific facts. Accurately representing a scientist means accurately representing the pieces of knowledge they convey on a particular topic. Accurately representing a piece of scientific knowledge means presenting it as it appears in a scientific journal. Accuracy of representation is synonymous with 'getting the facts right'.

WMW: "by getting something wrong what do you mean?"

> Producer-Director C: "a fact wrong or something, you know, there's a weight in [a programme I made] that's wrong, and there's an eyeball that's the wrong shape"

This desire to get the facts right can cause serious tensions with more senior figures who are more concerned with making an engaging programme. One interviewee (a PD) described the heated debate surrounding the way in which the details of a large engineering project should be represented. This debate centred around how to graphically represent the potential impact of a tunnelling project on a famous landmark. A contributing scientist had given the PD a very specific indication (to within a number of inches) of how much the landmark would have moved as a result of the tunnelling project. This shift was described by the contributing scientist as a serious problem with serious architectural and engineering consequences. However, the shift in the landmark's position would have been unidentifiable to the naked eye. Graphics were produced which instead of showing this small shift, depicted the landmark falling to the ground. My interviewee said he argued against this inaccurate depiction but then suggested his executive producer had told him he "didn't give a damn about accuracy and just wanted to grab the audience by the balls". In the finished programme the landmark is depicted as toppling to the ground. This sequence takes roughly twenty-five seconds of an hour long programme, but the debate surrounding it in the edit was described by the producer as contributing to the ending of his working relationship with the production company.

This story of course shows that on occasion the desire to accurately represent scientific facts can be completely outweighed by the demand to engage an audience. However, examples of this explicit disregard for factual accuracy were very rare in my interviews. What this and the former quote show is that it is the accurate representation of science facts that counts as accurate representation of science.

Representations of other aspects of the reality of science inspire less tension and debate between PDSs and EPs when they are not faithful. The following discussion of the representation of scientific knowledge that is yet to be established, i.e. that is controversial, illustrates this point.

> Executive Producer E: "With [a programme I made] there was a lot of complaints that went on and on about whether our explanation of entropy was correct, so there are competing ideas of entropy and the idea of the heat death of the universe and so on, we presented the heat death of the universe as pretty well a fact, there are people who think that the heat death of the universe may not happen, so should we have reflected that? Maybe, maybe we could have qualified it a bit more but that's where the tension tends to lie in those kinds of programmes"
>
> WMW: "and that's the same sort of conflict between educating and entertaining, that's the same sort of idea- "
>
> Executive Producer E: "I mean we never set out to get it wrong obviously, but what you do set out to do is make it as entertaining as possible and so the risk is that faced with two competing theories, one of them feels exciting and new and different and one of them feels a bit kind of like 'how the hell are we gonna make that interesting?' You pick the one that's got the biggest potential television impact and I think that's by and large fine, so long as the audience isn't given the impression that that's the only show in town. In the end, when you get to the frontiers of knowledge, there are different ideas, and the evidence isn't in yet to conclusively prove one or the other and I think part of our job is to inspire and excite people around the science and so I think it's quite legitimate to tell stories in a way that achieves that"

Controversy is an important part of the reality of science. Scientific knowledge is altered and new scientific understanding established through controversy (Collins 1992). However, this aspect of the reality of science, this process, is not subject to the same criterion of accuracy of representation as factual knowledge during non-fiction science film-making.

When the film-maker is presented with a scientific field in which facts are yet to be settled; a field where a controversy is ongoing, the film-maker chooses which side of a controversy to represent based on which side they believe around which it is possible to construct the most engaging film. This has two problematic consequences.

The side of the controversy which is represented may be represented accurately. However, by choosing only to represent one side of the controversy, those ideas that are represented will take on the appearance of being uncontroversial. Representation of this kind attributes the same status to the controversial idea as is attributed to other uncontroversial ideas that might be represented in a film.

Within the world of science, some facts are better established than others. In non-fiction science films, this distinction between well established and controversial ideas is less clear. The absence of representation of both sides of a controversy means that scientific ideas are represented as uncontroversial, whether this is the case in scientific reality or not.

The further consequence for a lack of representation of controversy in science is that the controversy does not appear to be an important aspect of the scientific process. If representation of controversy is uncommon in non-fiction science films then it will appear to a television audience that controversy is an uncommon phenomena in science, rather than an important aspect of scientific reality.

The above quote does suggest that the film-maker accepts that when scientific knowledge is yet to be settled the audience needs to be made aware that there are alternative perspectives. However, the fact that a previous programme made by this EP had not included these alternative perspectives and had received complaints shows that it is possible to produce a non-fiction science programme that does not represent an ongoing scientific controversy.

Further evidence that the process by which specific pieces of scientific knowledge were established does not have to be faithfully represented comes in the following;

> Executive Producer E: "In extremes you can manipulate the information a lot and then the question becomes, would

> somebody who knows that story from outside the BBC recognise the story you were telling? And often they didn't, because we'd manipulated it so much, now that's fine so long as you've stayed true to the facts, but often, what's called a fact is quite hard to pin down, so for example you might play with the order of events you might not tell it in a narrative chronology, because you might want to follow one person's point of view for a while and then pick up somebody else's or whatever, but what that has the effect of doing is, "well of course we knew at this point what that was, but you're pretending that we didn't", you know, and so that's the sort of thing that can get you into trouble"

"The trouble this can get you into" is with those scientists who were involved in the production of the scientific knowledge. The scientists involved in the production of scientific facts "knew at this point what that was" and may resent and complain about these aspects of the process of science being misrepresented. However, this is not the sort of trouble that has a lasting impact on a film-making career. If the film is successful, these complaints are quickly forgotten about.

This quote reinforces the idea outside the narrow confines of scientific facts, film-makers do not feel that other aspect of scientific reality require faithful representation. The 'scientific facts'; the content of the discovery, must be faithfully represented. The 'historical facts' of science; what happened when, the process, who contributed and at what time, the context of discovery, can be distorted.

Of course, the engineering programme that misrepresented the factual information provided by the civil engineer shows that it also possible to produce a non-fiction science programme that mispresents uncontroversial science facts. However, the attitude expressed in regard to inaccurate representation of controversy or process is very different to that expressed in regard to inaccurate representation of facts.

PD's hate it when they get facts wrong, and misrepresentation of facts can cause major arguments in the edit. Though the quote discussing controversy comes from an EP, who may be expected to be less concerned with accuracy, there is little reference to the inaccurate representation of controversy or process causing internal tension during production. It is described as accepted practise to represent the most engaging side of an argument, or to manipulate the historical process of scientific fact creation if this creates a more engaging film.

Misrepresenting scientific facts is seen as a failure, at least by some members of the production process. This is because representing scientific facts faithfully is a formative aspiration of the scientific film-maker. Faithful representation of scientific facts is aspired to:

> "We never set out to get it wrong, obviously,"

But faithful representation of scientific facts is not always achieved and when it is not it can be recognised as a moral failing;

> "So if it's a lie then that for me, ethically, sits really badly"

Representing both sides of a scientific controversy faithfully is not a formative aspiration of the film-making community. Nor is faithfully representing other aspects of the scientific process. Failure to represent controversy or process accurately does not inspire the same kinds of internal tensions, nor the same sense of moral impropriety.

This reveals a problem with science film-making from the perspective of the public understanding of the process of science (PUPS). PUPS scholars argue that the most important aspect of science that the public need to understand is the process by which scientific facts are established (Collins and Pinch 1998). Scientific facts are established through the settling of controversies. Lack of representation of a controversy can mean the controversial, unestablished fact appears to have the same status as a more established (uncontroversial) fact. Absence of representation lessens the role of controversy in science, making it appear unimportant in the creating of scientific knowledge. If science film-makers do not recognise a need to accurately represent the process of science in their programmes, then their programmes will not communicate these important aspects of science faithfully.

The fact that representing science faithfully is equated with getting the facts right is a result of the demand that science films engage an audience. Science-film-makers think the most effective way of engaging the audience for long-form science programmes is through constructing within their programmes clear, linear narratives, with an obvious beginning, middle and end and using other narrative tropes drawn from fiction. This requires them to manipulate the messy aspects of the scientific reality; the process, the controversies, so that they fit within this kind of narrative structure. Scientific facts, taken in isolation, can be simultaneously made to fit into a narrative of this kind and accurately represented. Facts written in a journal, or voiced by a contributing scientist can be located within a narrative which manipulates the context of their creation without alteration to the isolated fact. Scientific processes cannot be simultaneously narrativised and faithfully represented. It is impossible to faithfully represent how scientific knowledge is or was created if timeframes are altered, information withheld, or controversy ignored. Attempting as much as possible to accurately represent scientific facts means film-makers meet the requirements of non-fiction science films to faithfully represent science, whilst not undermining their attempts to make their films as engaging as possible.

> Executive Producer F: "so the contradiction then between science and story when you're trying to tell a narrative is that you've gotta be sitting within the facts but what scientists often find hard is the freedom that we take upon ourselves as storytellers to control the story."

The Long-form Documentary Makers' Model of Science

The importance of this commitment to narrative as a primary method of engagement, and the resulting impact it has on representation of scientific process, is evident from the value that is placed on having a scientific background in the science film-making community.

It is arguable that the individuals best placed to faithfully represent a reality are those who have the most experience of it. These individuals are privileged with an insider's understanding of this reality and should be best placed to produce faithful representations of it. However, producing a faithful representation of science is one demand of non-fiction science television which is weighed against the competing demand to produce an engaging film, a demand satisfied through the use of fictional narrative devices.

Undergraduate scientific experience is perceived as providing some benefit for the individual involved in film-making, and some individuals having experience of science is perceived as benefiting the film-making endeavour as a whole. Undergraduate training provides skills useful in the film-making process. It also instils a model of science which views science as discrete, isolated facts, and ignores social processes, a model that makes science filmmaking easier. However, experience of science is certainly not a pre-requisite for science film-making. The skills required to make science films can be acquired in other ways. Individuals with no science background will also help to ensure that the programme remains engaging, their lack of knowledge allowing them to act as audience proxies. Most revealingly, having too much experience of science can be a problem for a film-maker, and can have a negative impact on the films that they make. Too much experience equips film-makers with an alternative model of science which does not align as comfortably with the techniques film-makers employ to satisfy the demand for engaging films. This model must be jettisoned if an individual with too much experience of science is to be a successful science film-maker.

Having a science background vs not having a science background

When working in science television, possessing a background in science can be useful in certain ways;

> Senior Executive J: "It's handy to have a scientific background, to be able to be reasonably scientifically literate when you're doing research for a programme because obviously science can be quite specialist and quite tricky as subject matter"

Individuals with an undergraduate education in science will be more familiar with scientific information and may find it easier to source and subsequently understand this information. Science graduates may require less time to get up to speed on particular scientific topics or have a better grasp of the interesting material within a field. They will be able to fact-check, an important aspect of science television production. Employing science graduates therefore simplifies the job of producing a film to an extent, as they already possess some of the important knowledge and skills required to find and assess science content for films.

A more advanced background in science, such as a doctorate, confers some further advantages. It was suggested that science PhDs have an understanding of the scientific method which allows them to identify reliable research. This can include having a better grasp of mathematics or statistics so the numerical component of research is understandable. This will also mean understanding statistical power and error, so the strength of claims made in a study can be personally assessed. PhDs are also better at assessing the merits of different studies as they understand the status difference between journals.

> Executive Producer F: "Having a PhD is useful, in so far as it gives you an understanding, a quick way into understanding the science method, and techniques so you can actually sort out good science from bad science very quickly, and decide the merits of work on the basis of what's its scientific value, inherently, so that's a good thing it gives you a bit of a short cut"

> Producer-Director C: "Getting at the research, knowing how to find papers, which journals are the journals that are the most respected, there's just a lot of background so three years of learning how to do that before even worrying about television is really useful"

PhDs also have the ability to converse on a shared level with contributors to their programmes, which may help to smooth the process of research further:

> Producer-Director C: "What I find is very important, just having doctor in front of your name means that when you go to talk to people who are professors or doctors or something, there is a different way they approach you and you approach them…I don't feel it's difficult to talk to academics at all, and I think that is really helpful. I've met researchers who've come in from other subjects and they find it harder, you have a whole load of getting up to speed on the research process and the tools and trying to read things in a language that isn't, you know-"
>
> WMW: "so it gets you close to the level of your contributors, and you can talk to them?"
>
> Producer-Director C: "Yeah, exactly, exactly,"

Having a science background simplifies certain aspects of the film-making process. University science training may equip an individual with the knowledge and skills to understand the scientific content fact check more easily. This can be helpful in the research phase of a programme. More advanced experience and knowledge can be helpful in other ways; knowing which journals to look in, assessing the quality of a study and being able to talk to scientists are all useful skills for a film-maker. These skills all help production run more smoothly, saving time and effort (and as a result money) during production.

Experience of carrying out scientific research, holding a science degree or any subordinate qualifications in the sciences is, however, not necessary when making science TV.

> Senior Executive J: "my unit, my science unit in the BBC had lawyers, historians, social scientists, English graduates, to be honest as long as you can handle complex information and can work on evidence, evidence based argument as you're constructing a story, having a science background is not a hugely important thing in my view"

When applying to enter the industry, a 'good undergraduate degree' in any topic is generally considered the basic requirement.

> Senior Executive S: "If I'm looking to hire people now as producers or researchers, I'm always just looking for a kind of

> a solid degree, not necessarily in media, in fact probably not, it would put be off slightly just because I think it's more important to get a good academic discipline in any subject before you get into the area of research"

When hiring new staff, particular qualities associated with individuals who have university qualifications are as or more important than a science background. Qualities such as curiosity, an enquiring mind and the ability to ask the right questions, locate relevant sources and condense information so as to make it easily transmittable to a non-expert audience were all described as important. All of these skills are particularly relevant to the role of the researcher, the typical entry level position for a university educated individual in the science film-making profession.

These skills were equated with those required for journalism and my respondents often described the close resemblance between journalism and science documentary making.

> Senior Executive J: "It's journalism, that's really what it's about, I mean you're journalists when you're making programmes; you are finding out information, you're asking the right questions, you need curiosity, you need the ability to draw insights from information"

Though science education may provide some shortcuts to those who possess it, it is by no means necessary to carry out the work of science television production. The skills required are provided by general university education and are in many ways synonymous with the skills required in journalism.

Though the skills provided by science or non-science training are broadly the same, undergraduate science training does more than impart a set of skills. Undergraduate science training also produces a particular perception of how science works. It is this perception, or model, of science, that is as important as the skills undergraduate training provides.

Undergraduate science is organised around the dissemination of a paradigmatic set of beliefs (Kuhn 1962). In an undergraduate science programme uncertainty and novelty are suppressed and science is presented as a clear set of readily identifiable principles and precepts (Delamont and Atkinson 2001). Only at the forefront of research, within the core-set, do scientific facts seem uncertain, controversial, and difficult to produce (Collins 1992). As one moves away from the core-set, uncertainty is replaced by the certainty of text-book knowledge ("distance lends enchantment").

Undergraduate science does not expose the inner workings of science. The social processes of science are not made apparent. Undergraduate science is the canonical science of Chapter One. If science is understood as a set of clear, definitive facts, then faithful representation of science will mean faithfully representing these facts. The processes which led to the production of these facts will not require the same kind of faithful representation. In this way, undergraduate science training prepares individuals to enter the film-making community, whose priorities of faithful representation of science and engaging programmes are met through producing programmes which adhere to the facts of science, whilst manipulating the process.

Individuals without this background are less certain to possess this background. However, due to the widespread nature of the canonical model, and the likely avenues through which they have come into contact with science previously (education and the media), that they will hold this model is not unlikely. If they do not, their work as film-makers will soon inculcate within them an understanding of the priorities of the community.

Individuals with no scientific experience are in fact useful in the production process due to their relative lack of knowledge. This lack of knowledge means they are better able to ensure the scientific facts that are communicated in way that is engaging for an audience.

> Producer-Director B: "I've never done a science degree… I think actually its turned out to be a bit of an advantage in terms of doing the programme because you can break it down for the layman, because if I don't understand it, then the people at home won't"

Science undergraduates and those with no experience of science are useful in the production of science films. Science undergraduates' model of science aligns with that required by non-fiction science television. This is also most likely the case for those with no science training. These individual's lack of knowledge further aids the programme-makers to satisfy the demands of an engaging programme. Individuals with no knowledge of science can act as audience proxies, adjudging whether the film's content will engage a lay audience. Both science undergraduates and those with no science experience have an understanding of science that helps to ensure a programme is as engaging a possible.

Knowing too much science

Having too much knowledge or experience of science can be problematic.

> Executive Producer M: "I had gone from being a post-doc to being a junior researcher, which is not the end of the world, but it's a bit of a shock. I found that the way TV was dominated by the story and the image very hard at first, because as a researcher I wanted to get in background and context and TV wants a story with good pictures…there was quite a strong culture clash, at the time, and it didn't take me that long but I had to do a fairly major readjustment of my own way of thinking about what counts as research, what counts as a story and things like that"

The individual with too much knowledge must adjust to the requirements of television. They must shift perspective from scientist to science film-maker in order to make successful films about science. If individuals do not readjust their perspective, problems can occur. It was suggested that individuals with comparatively large amounts of science experience (by the standards of television; a PhD in a science subject or above) could occasionally 'go native';

> Executive Producer F: "there is quite a few people have PhD's but I don't think that necessarily makes them good television directors and producers, they're not necessarily thinking visually, they're thinking about the science perspective but not about how the message is going to be consumed"

For this interviewee, 'going native' or 'thinking about the science perspective' means trying to convey information in ways which would satisfy the scientific community, but which would not make good television. Presenting novel scientific claims with caveats of uncertainty attached would seem appropriate to a scientist, but would undermine some non-fiction formats requirement for clear-cut answers. Acknowledging the previous contributions of peers to a research field is standard scientific practise, but allowing contributors to do so on television can detract from the clarity of the film. Focusing on the specific details of a piece of research and its local application, which most research is addressed towards, rather than possible fundamental shifts in understanding, downplays the novelty and significance of the science being presented, risking audience disengagement. The film producer who has gone native does not satisfy the perceived demands of a television audience, who require simple messages delivered with clarity and certainty.

Thinking like an undergraduate is preferable in science television. This kind of thinking facilitates a forgetting of "the science perspective". If science is thought about in this way then scientific uncertainty, the context of discovery and the other things important in 'the science perspective' are unimportant. It is easier to leave out the hedges, caveats and uncertainties. Thinking about science in this way helps the film-maker in the production of engaging films. Seeing the process of science as unimportant means it does not have to be faithfully represented. These aspects of science can be represented in any way which furthers engagement. As long as the facts are accurately represented, then the film can claim accuracy of representation, whilst it can maximise engagement through the compelling representation of other aspects of scientific reality

Knowing the right amount of science

In order to enter into and be successful within the world of science TV-making, scientific experience and expertise is by no means necessary. It can in fact be problematic.

The community of science film-makers values some of their members possessing some background in science. Acquaintance with a scientific subject makes research easier and quicker. Being able to fact-check and handle complex scientific information makes science graduates useful during the production of science television programmes. As well as providing these skills, undergraduate training inculcates a model of science that facilitates the production of programmes which satisfy the demand to be both faithful in their representations and engaging.

More experience of science[33] can make science television production harder. Understanding that scientific knowledge is uncertain, communally produced and reliant on specific processes means that faithful representation of science would include faithful representation of these elements. However, it is not possible to employ many of the techniques that science film-makers use to make their films engaging to produce a faithful representation of these elements of science. The model of science provided by more in-depth experience of science can jeopardise the production of engaging programmes.

What counts as a relevant and useful model of science for long-form science documentary making is undergraduate canonical science; science as a set of clear and definitive facts. Canonical science is relevant and suitable because it fits with the demands of television to engage an audience. A set of textbook facts are clear and definitive. They are easy to communicate with the clarity and certainty an audience desires. They can be more easily interred in a narrative format designed to engage an audience. More advanced models of science, which view the scientific process as more important, which undermine the certainty of scientific facts are problematic for the film-maker. Attempting to faithfully represent the processes and uncertainty of science creates a conflict between faithful representation and narrative devices

[33] Extended experience of science is not guaranteed to produce a contextual understanding of science. Many scientists are unaware or actively reject the contextual model of science identified by sociologists. However, a contextual understanding is more likely to be produced by this extended experience than by undergraduate training or a complete lack of experience of science.

employed to maximise engagement. This conflict is not apparent if faithfully representing science means faithfully representing isolated, certain, context-free facts.

> Senior Executive I: "if your 'sciency' or 'history'y', you have all sorts of different backgrounds that you can bring, that's what you need to make your programme factual and to fact-check and to make sure, but that's not, being a brilliant scientist doesn't help on the story-telling, what you need is to be a brilliant story-teller"

Non-Documentary, Non-Fiction Science Programmes

Due to the differing requirements of different audiences, different channels and different timeslots, science can be represented in non-fiction formats other than the long-form documentary. Lehmkuhl et al. (2012) construct a typology of five different non-fiction programme styles in which science can be represented. Popularisation Programmes, in their terminology, are made in the documentary format described in detail above. The four remaining formats differ from the documentary in various ways.

Informational Programmes are science-focused current affairs programmes. They report on recent developments in science in a current affairs style. Their production is similar to other current affairs programmes and is characterised by short preparation time. (There were no UK broadcasts of this kind of programme identified by Lemkuhl et al.). Edutainment Programmes "aim to educate and entertain the audiences with reference to scientific ideas and processes". They contain some scientific content but are based around popular non-scientific TV personalities (UK example: *QI; Duck Quacks Don't Echo*). Advice Programmes, provide hints and tips to the public based on scientific knowledge. Lay people are often central to these programmes (UK example: *Trust me, I'm a Doctor*). Advocacy Programmes have a political or social motivation, usually environmental, and contextualise science within this wider agenda (in the UK, programmes focusing on climate change, for instance *Climate Change: A Horizon Guide,* can be characterised as advocacy programmes).

These programmes will use different devices to encourage their audience to read them as non-fictional. The inclusion of 'real' people in Advice Programmes will, amongst other things, help to ground the programme in the non-fictional genre. Unscripted lay contributions may help to emphasise the programme's relation to the historical world. Informational style programmes may employ devices used in other current affairs programmes; live interviews or reports from sites of current scientific importance. The similarities of these devices to those used in other current affairs programmes will suggest to an audience that these programmes can be read like current affairs i.e. as relating to the real world.

As with the documentary mode, these different representational devices will shape how science is perceived by an audience. If science is presented in a current affairs format, it will be likened to current affairs. It will be viewed as changing, developing over time and open to new discoveries or dissent. If science is shown to have practical relevance to the lives of individuals it will be likely viewed in these terms.

Short-Form engagement: Format and Content

Short-form programmes will use different devices to engage an audience, as they lack the scope to employ the kinds of narratives used in long-form documentary.

> Executive Producer E: "so you can get away on a 6 minute tomorrow's world item without having any huge story-telling instinct, because in the end it's six minutes and the flow of information is going to be fairly predictable within that, there's not a huge amount to play with"

Different short-from programmes may attempt to engage an audience in different ways. They may draw on other programming genres for inspiration, to create an atmosphere, or give the programme a specific appeal different from that of long-form science programming.

> Executive Producer F: "I wanted to make a programme that was kind of irreverent but informative, that wouldn't be po-faced, that could actually show that science is something you can talk about. The actual point of reference for that was Graham Norton, Jules Holland and TFI Friday….So that was kind of thinking I just want this thing that felt convivial, informal and irreverent"

The programmes cited as influencing this film-maker are all studio based entertainment programmes. They include elements of celebrity talk show, live music and studio audience interaction with contributors. These kinds of techniques for engaging an audience are very different from the techniques used in long-form documentary science films. As well as engaging an audience in a different way, they produce a different representation of science

> Executive Producer F: "I wanted to feel like it was a space where it felt like anybody could drop in and actually just chat about stuff, to make it feel like science isn't esoteric, it's not distant, but it can be something you can chat about and converse about…it did science but it wasn't po-faced about it"

As suggested by Lemkuhl et al. (2012) these programmes may also hope to engage an audience through the relevance or topicality of their scientific content. Other programmes will attempt to show the relevance of science to everyday life, making the programme engaging through its practical utility for its audience. Informational style programmes will appeal to an audience that wants to keep abreast of the latest scientific developments. They will engage the viewer through providing a sense of receiving information on the latest scientific scoop.

These different representational devices do not exert the same pressure as the narrative used in long-from documentary. Aspects of scientific reality that are elided in the long- form documentary may be represented in short-form programmes. Current affairs style science programmes will discuss recent scientific developments. This will suggest an idea of scientific development and change. They may also include dissenting voices. Current affairs programmes are often built around onscreen argument or discussion (Örnebring 2003). Concurrently, representations of science in these programmes may suggest scientific debate. This will also be suggested by the chat show format, where contributors on-screen interactions will suggest scientific information can be subjected to debate and disagreement (Kress and van Leeuwen 2001).

The visual imagery will generally not be of the same aesthetic quality as that of long-form programmes. The reduced budgets, shorter production times and lack of scope to develop an overarching visual narrative will reduce the scope for the inclusion of emotionally stimulating images. The images of a short-form programme will not be designed as explicitly to attract an audience through their aesthetic appeal. The images of a short-form programme will be designed to increase the clarity of the communication of a programme.

Representational Modes and Audience Understanding

The form or format of a science programme exerts an influence over how science is represented before the content of the programme is even considered. A science documentary will tend to abstract away from the specific cases of the filmed elements and use expositional commentary and interviews to tell some wider truth about science and its relationship to reality. A current affairs format will locate science in the contingent, changing world of the here and now. An advice programme will show the practical relevance of science to people's lives.

These different modes draw the viewer's attention to different aspects of the specific reality that is represented. This in turn locates that reality beyond the programme in the viewer's wider understanding of the world. If a programme reveals the day-to-day realities of science then science is more likely to be be located alongside other aspects of reality that are perceived as ordinary or day-to-day. If science is depicted in the abstract expository mode, it will be connected to those other aspects of reality that are abstract, removed, other from the day-to-day.

Producing a factual programme about science which engages an audience involves a decision about which mode to employ to represent science. Which mode of representation is utilised in a specific programme is the result of the programmes position within the wider television environment, of most influence within which is the channel and time slot at which the programme is broadcast. Working within these constraints, a programme will be made in a presentational mode designed to represent science faithfully but more importantly, be compelling for the specific audience it addresses. In its quest to engage this specific audience, the format or mode the programme employs will shape how science is represented, and subsequently understood by the programmes audience.

The Purpose of Non-Fiction Science Television

Non-fiction science television programmes are designed to entertain. The primary purpose of the vast majority of television programmes is to engage an audience, to keep them watching. Non-fiction science television programmes are no different. They are subject to the same rationale as other television programmes. Though the specific ratings expected for a scientific television programme may be less than for programmes from other genres, a science programme is still required to engage as large an audience as possible.

Science film-makers understand that the primary purpose of their programmes is to engage an audience. This, however, does not mean that film-makers think their programmes do nothing but entertain. Some film-makers are concerned with the accuracy of the specific information communicated as they believe science programmes should impart scientific knowledge to an audience. These film-makers are in a minority. A more widespread attitude is that science television programmes can generate interest in or enthusiasm for science. Though television may be incompatible with informing an audience about the details of science, it can affect how science is perceived by an audience. Through their programmes, science film-makers can generate positive public attitudes to science.

> Executive Producer Q: "It is about trying to get other people as excited about the subject that we get interested in and engaged with"

> Senior Executive N: "you shouldn't underestimate just how an important trigger what we do can be for people at all different stages of their lives, and the number of people who still talk about the fact that they saw a Horizon in their teenage years that inspired them to go off in some direction…so it has impact, people change their relationship with science, what they want to study, what they want to be because of the way that we portray science and scientists"

> Senior Executive N: "I said that we're part of the education system but we're not really educators, most people don't have a relationship with television where they'll remember detail 2 weeks later, so we're inspirers of education as much as we are educators""

> Executive Producer F: "I think I'm here to interest the audience, I don't think the job of television is actually to educate people about the detailed minutiae and all the rest of it, they can go and find that, it's actually to make them interested, to broaden them in a way that makes them a bit more interested and curious about the world and ask questions of other things, that I would say would be all I I'd truly hope to achieve"

Overwhelmingly, generating this kind of public support or enthusiasm for science was viewed as unproblematic, a worthy goal of science film-making. In viewing television as a medium for promoting public attitudes towards science, television makers and the scientific community are aligned.

Scientists and the Media: Friends with Benefits

An ambiguous attitude towards media coverage of science is present within the scientific community. Misrepresentation is cited as a primary concern of scientists when discussing media representation of science (Peters 2013). In general, they view media representations of science as neither wholly positive nor negative (Peters 2013). However, within the community as a whole concerns over misrepresentation are balanced against the perception that media representations can increase public support for science. For Peters et al. (2008) the goal of improving public attitudes toward science is the primary aim of those scientists involved in media work.

Interacting with the media is an aspect of the scientist's role that has become more prominent. Contact between scientists and media happens frequently and a significant number of scientists have contributed in some way to media communication of their science (Peters 2013). Media representations direct public attention towards certain issues and away from others. Scientists believe that representation in the media makes scientific work appear relevant to the public. Showing the relevance of science is believed to increase public support. Engaging in media work allows scientists to satisfy the demands placed on them by their institutions and funders to make their work visible to the public in order to increase public support and funding for science.

> "Catalysts for this change of the scientist's role are research organizations (e.g., universities), which consider visibility in the media as an important way to secure public and political support" (Peters 2013, p. 14105)

Scientists are ambiguous towards general media representations of science because they assess it in terms of the accuracy of its content (Peters et al. 2008). Scientists tend to view their own interaction with the media, if they have had any, in positive terms. Scientists are happy in their own interaction with the media as it allows them to satisfy the institutional demands placed on them to make their work visible. However, in so doing they must accept a degree of inaccuracy of representation.

Some scientists are more willing to do this than others. They tend to be higher status, more senior scientists who understand that the benefits of public support outweigh the potential problems which result from misrepresentation.

Within the scientific community, it is viewed as more acceptable for higher status individuals to expend their time and energy on science communication activities, compared to more junior colleagues (Peters 2013). Media professionals are likewise more likely to want to talk to scientists in positions of leadership or authority within a department or research team, and who are research productive (Besley and Nisbet 2013). This aligns with information received during my interviews:

> Senior Executive J: "when you're making programmes around science, you are dealing with some of the top people in the their disciplines in science, you can pick up the phone and get through to a Nobel prize winner, head of a research department or whatever, with no trouble at all, and those people, generally, are the most adept at conveying their subject, they have got where they've got partly because of their ability to convey their subject matter"

The ability of high status scientists to communicate science (to audiences both within and beyond their scientific community) is viewed as fundamental to their success by this film-maker. This communicative ability makes these scientists attractive to television producers. Their awards, accolades and positions of authority will legitimise and add weight to the content of a film and their ability to communicate clearly and concisely will make it easier for the film-maker to satisfy the demand for a programme to engage an audience.

The academic presenters I interviewed, when discussing attitudes to TV science communication work within their fields, suggested that more junior and more high status individuals recognise the fundamental importance of media work to science, compared to their intermediary peers;

> Presenter T: "people that are really junior I think get it, and people that are really quite senior get it, I think the ones in the middle, the academics in the middle, struggle a little bit more and the reason for that is, the ones that are young just don't know any different, they just think telly's great, they've been bought up maybe on programmes with myself so it seems quite

> natural, the ones at the top have gone through the whole process and realised, have either had experience of television themselves or they've realised that the academic world is not the be all and end all and there is another world out there and this kind of thing's important"

> Presenter R: "but attitudes have changed, more and more universities now have people in place like me, chairs in public engagement in science, more and more academics are saying what you do is really important for our field"

Intermediary scientists may be less willing to contribute for a number of reasons. Due to the increasing pressure to 'publish or perish' active research scientists in the middle of their careers may not have the luxury of time to commit to television programmes. They may feel that negative consequences of misrepresentation outweigh the potential benefits of increased visibility.

> Presenter T: "the ones in the middle are the ones that are on their academic career path, that have made the decision to go for the standard which is research papers and research grants, find any of the television things a distraction, unwelcome, maybe problematic, maybe had bad experiences, and doubly that kind of underlies it, and so that's the places where you'll sometimes get some resistance to what you're doing"

> Presenter T: "there is a feeling I think amongst some [scientists] that science television is an extension of the lecture room, that the way that they, you know, there's a topic, they give a lecture on that for an hour, they watch a television programme on it, it's completely different and so the television programme is deficient cos it didn't cover any of the stuff or most of the stuff they'd do in a lecture"

For those scientists who are willing to engage in media work, their goal is clear (Peters et al. 2008). They accept that total accuracy of representation is unlikely in the media, but are willing to accept this if public support can be garnered. Scientific organisations view media communication as a vital channel for securing public support for science. Communicating in the media satisfies the institutional demand for scientists to make their work visible to the public in order to generate public support. Scientists are willing to accept inaccuracy of representation as long as the work is visible, as visible work is more likely to increase public support than un-publicised work. In this sense, scientists approach media communications as a form of public relations.

> Presenter T: "It's like I'm involved in public relations for my science, I'm out there trying to give out warm feelings [so] that [people] might think that what my subject does is interesting and kind of cool, and I want people to come into it, either students directly, or other people to say 'oh that science lark, that's quite good' that's kind of enough for me"

"I'm a Failed Doctor": Cheering from the Side-lines of Science

That this public relations motivation is so easily satisfied by scientists in their interactions with the media reveals something about the relationship between science and media professionals. If scientists feel they are able to improve public attitudes to science through the media, they must believe that media professionals facilitate this through their media products. At least, certain sections of the media are willing to attempt to promote positive public attitudes through their representations of science. This appears to be the case with much specialist factual science film-making. One of my respondents expressed this attitude quite explicitly:

> Executive Producer P: "I see the world of factual film-making split in two; there's the people who uncover the bad stuff which is important work, and then there's people like me who tell the stories of the great discoveries and the great achievements and I see television as a way of telling lots of people about something, it's a one-to-many system and I feel it's great to be able to make films that tell people about other great people and other great achievements that humans have done, so my films buy into the whole celebratory nature of progress and science as being a really important part of that"

Though specialist factual science film-making involves some elements of journalistic work, it does not involve the kind of investigative journalism which is applied to other public institutions. The kinds of scrutiny that sections of the media may apply to other public institutions (e.g. politics) is not often applied to science by specialist factual film-makers.

Other film-makers may approach science from a more critical standpoint. One of my respondents suggested that the documentary maker Adam Curtis adopted this more critical stance to science in his films. However, this respondent was critical of his films for this reason;

> Executive Producer P: “Adam Curtis, whose films I hate and loathe, because his philosophy is the opposite of mine, his films are a constant complaint about progress and technology, whereas I think progress and technology are a wonderful thing, I’ve never met the guy but I assume he thinks the opposite if I’m judging by his films”

Whilst the fact that a number of my respondents suggested that their films were designed to generate enthusiasm for science reveals something of the attitude towards science held within the science film-making community, the absence of a contrary view is also telling. None of the film-makers I spoke to expressed a desire to hold science to account, to critique or to question science. Though it was suggested that films that adopt this position can and do get made, they are not the kind of films that are made by ‘science film-makers’. My respondents had all made their science programmes in-house at the BBC science unit, or for commercial production companies which specialise in the production of factual science programmes. These production spaces are characterised by a positive attitude towards science, and a desire to propagate that positive attitude amongst the general public.

That enthusing an audience and increasing public interest in and support for science is viewed as a worthy goal by science film-makers is attributable to the status attached to science by many people in modern western societies. The canonical model of science (prevalent in the science film-making community, and wider society) not only provides an image of science as a producer of objective, neutral, asocial facts, this image of science is fundamental in locating science as the human endeavour *par excellence* . Science’s synonymy with epistemological objectivity enhances its moral and social status.

> "The prestige of science is so great that it is believed to possess such authority and be able to answer any of life's questions. This is so because science is widely believed to transcend the social forces that obviously shape other human institutions, such as politics or religion. Science is believed to be, in a word, 'objective'." (Toumey 1996, p. 6)

When science is understood in these terms, the promotion of positive attitudes towards science is an obviously worthy goal. In the response to the encroachment of other systems of belief or understanding, the science film-maker has a duty to promote the scientific worldview, a worldview founded in rationality and objective evidence. Science programmes can form a bulwark against the rising tide of un-scientific thinking.

> Senior Executive J: "around about the time of the Darwin anniversary in 2009, the profile of creationism in the media was actually building to some degree at that time, in the year or two before that, so it was my (Science) department and I who were instrumental in persuading the BBC commissioners to have a big anniversary season built around evolution…I think absolutely it's the role of broadcasters, certainly the BBC, but I think broadcasters in general to demonstrate the significance of rational thought, and to separate off, you can have belief if you want belief, believe in the moon being made of green cheese, you can do that, but it's not rational evidence to… you cannot equate that with factually based, evidentially based programmes, subject matter, and so I think it's absolutely the role of the science programme-maker to notice trends in the body politic and to offer up scientific underpinning of argument or debate on one side or the other"

> Senior Executive K: "how science works, its process, its narrative of gathering evidence, making judgements making evidence based assessments, proofs, all the rest of it, is again a fundamental principle of, frankly of western civilisation, of the society and culture in which we live…that incredibly important methodology which has been around, lord save us, for two and a half thousand years or whatever, that really important methodology has to be something that we talk to and we celebrate

This tendency to adopt an uncritical perspective toward science amongst science film-makers can possibly be emphasised by film-makers individual experiences with science. Many of my respondents had previous experience in science education, or for one individual experience of working as a scientist. For some at least, this education was undertaken in the hope that it would lead to a career in science. For various reasons, these individuals' aspirations to work in science had not been achieved.

> Executive Producer M: "At the end of my post-doc the story I tell is that I realised I was much better at talking about science than I was at doing it, which is probably not uncommon, and I was looking around doing my post-doc thinking well what am I going to do next because it dawned on me that I was not going to be the world's greatest academic scientist"

For some of my interviewees, a job in the media communicating science was viewed as the next best option after the pursuit of career in science was unsuccessful.

> Senior Executive N: "I'm a failed doctor, I wasn't very good at physics and didn't get the a-levels I wanted so I went to university, did a degree in physiology and pharmacology, which was in the medical building but not in medicine, popped out the end of that, tried to get into medical school again, failed again, they didn't want to take my degree, so didn't have much to do and saw a master's at Imperial College in science communication in the back of New Scientist, and just went and did it"

For these individuals working in science communication allows them to retain a tangible connection to the world of science. They can claim to be contributing to the scientific endeavour, through inspiring the next generation of scientist, or the increasing support for science amongst the public more widely, without being scientists themselves. In this way, science film-makers are working in service to an institution to which they attach a great deal of prestige.

Through their programmes, science film-makers do not intend to educate, but they do not intend to misinform. Factual accuracy is important, but engagement more so, as facts will probably be forgotten. Fidelity to the process of science is only required if this enhances the programmes potential to engage, if it hinders this engagement potential then fidelity to the process is not required. A programme that engages an audience, as well as ensuring high-ratings, will enthuse an audience about science. Increasing positive public attitudes to science is a good thing in the eyes of both film-makers and scientists. For scientists, the material gains as a result of increased public support are obvious. For film-makers, increasing public support for science is linked to their canonical understanding of science as the prestige institution of modern societies. In some cases this desire could be heightened by individual aspirations to further the scientific endeavour which were not achievable for these individuals as scientists.

Conclusions

Non-fiction science television programmes are entertainment products made to engage a specific audience. The reaction of this audience to the product; how many people watch it, and to a lesser extent how much they appreciate it, will define, within the science TV making community, the success of the programme. Successful programme-makers get re-commissioned, so film-makers are in the business of making successful programmes. Success is not guaranteed – it is often difficult to predict which films will be successful – but film-makers seek success through understanding their audience, and catering to their perceived desires. What an audience desires, and will be engaged by, is influenced by the channel which airs the programme, and the time-slot in which the programme is broadcast.

Programmes made for the 9pm slot can shape the scientific content of a film around narrative structures from fictional genres to engage an audience. The images of these films must be of the highest quality. They must appeal aesthetically to an audience in order to match up to competing programmes broadcast simultaneously on other channels. Early in the evening, audiences are engaged in different ways. Due to the lack of attention that can be devoted to the television, an audience will require multiple entry points into a programme. The scope to shape content around fictional narrative structures is reduced, as audiences for these programmes will not follow a complicated story. Borrowing from other genres (current affairs, chat-shows and magazine programmes) may occur, but these early evening programmes will be designed to engage an audience whose attention levels will fluctuate throughout the programme.

The different techniques utilised to engage an audience will impact on the way in which science is faithfully represented. The expository documentary format presents a set of abstract statements about a reality, designed to shape audience perceptions of that reality. This representational form, though grounded in historical reality, abstracts away from the day-to-day, utilising the images of the world to make broader claims beyond what is immediately represented. Alongside this, the narrative devices film-makers use to make their documentaries engaging, further elide aspects of scientific reality. These aspects; the uncertainties, the processes, are the very aspects that it would benefit the audience to understand. The pressure to make engaging films which satisfy the demands of an audience but which remain grounded in the historical world means in science television's most prestigious format, the long-form documentary, science is depicted as a set of isolated facts, which though (generally) accurately represented in and of themselves are divorced from the context of their construction.

The production of this kind of representation of science is made easier because the working model of science adopted within the programme making community is an undergraduate model of science. Knowledge and understanding of science is useful for non-fiction science film-makers, but only up to a point. Too much knowledge and understanding of science, produced through post-graduate or more advanced experience, of the kind which is likely to help an individual develop a more contextual model of science, is not useful. This level of knowledge can hamper film-maker's efforts to produce engaging films. If film-makers have this higher level of knowledge, they will require a readjustment of perspective, to align with the undergraduate model widely adopted in the community which facilitates the production of engaging programmes whose claim to faithfulness of representation lies in their factual accuracy.

Regardless of format, the amount of information a science programme is intended to impart is limited. What a programme is intended to do is to promote a positive attitude towards science within its audience. Producing television programmes which expose as many people as possible to science, and enthuse them about it, is, for science film-makers, their worthy and valuable role. Non-fiction science film-makers are enthusiastic in this role for a number of reasons. Individual life histories and the desire for personal affiliation with the scientific endeavour can be enrolled in justifications for the project of public relations for science. However, more fundamentally, the influence of the canonical model of science is widespread amongst non-fiction science film-makers. Science's perceived relationship to truth leads to a normative judgement of science's goodness for society. As truth-making endeavour *par excellence*, science is the prestige enterprise in modern societies. Viewed in these terms, improving public attitudes towards science can only be a good thing.

In describing some of the salient aspects of the world of non-fiction science television production, I have hoped to show how it is possible that the different representations of science that I will describe in the next chapter are producible. The production of these differing representations is facilitated by the matrix of interconnected institutional, professional and genre pressures and constraints described above. Non-fiction science programme makers must engage an audience. The characteristics of that audience, defined by channel and time-slot will define the techniques of engagement programme-makers employ. In turn, this will impact which aspects of scientific reality are chosen to be foregrounded, and which to be elided, a choice made always in service of the engagement potential of a programme.

Short-form programmes are less dominated by narrative, and engage their audience in different ways, from their long-from counterparts. The formats used in short-from programmes are more varied, and include representational devices that can emphasise dissention, disagreement and uncertainty. The lessened influence of closed-form narrative means short-form programmes can represent science in ways that reveal some of the processes of production, the uncertainty and debates. It is this kind of more nuanced presentation, which represents the uncertainties of science, the debate which it involves and its ambiguities that characterises the secular portrayal.

Underlying the decisions about how best to engage any television audience with scientific content is the normative commitment to the improving of the public's attitude to science, a commitment that is justified by an epistemic model that views science as a producer of truth. This model of science simultaneously reinforces this normative position and results in the production of uncritical representations of science. Emotionally stimulating, awe-inspiring images alongside closed form storytelling which present isolated, perfect and immaculate scientific facts divorced from the context of their production is evident in the religious portrayal of science. It is to analysis of these contrasting portrayals that I now turn.

CHAPTER 6
SCIENCE PORTRAYED: RELIGIOUS AND SECULAR PORTRAYALS IN NON-FICTION SCIENCE PROGRAMMES

The competing demands and pressures of the making of non-fiction science television programmes necessitate the production of different representations of science. Even within the institutional and genre constraints of the production process, there remain a number of representational devices film-makers could use to satisfy the demands of engaging an audience with faithful representations of science. The results of the choices made by non-fiction science film-makers within the constraints of their profession are diverse representations of science, representations which are then presented to a mass audience. Therefore, it is important to analyse representation of science in specific non-fiction science programmes as these representations will have some effect on their audience's understanding of science. In this chapter, I therefore analyse two specific ways in which science is represented in non-fiction science television.

The chapter contains the results of an ethnographic content analysis of two non-fiction science programmes; *Wonders of Life* and *Bang! Goes the Theory,* first aired in the UK in 2013. Both programmes were broadcast on mainstream UK television channels (BBC Two and BBC One respectively) during the part of the day the science programme-makers I spoke to described as the main television-viewing period for most households in the UK. In this sense these representations are mainstream representations of science, and could be expected to reach a mainstream audience. The representation of science in each has the potential to reach a broad, national audience and to shape this audiences understanding of science in specific ways.

I will analyse these two programmes in order to understand how each programme portrayed science differently. To do this, I will explore the relationship between the talk, image and soundtrack used in each programme. Out of the interrelationship between these different semiotic modes in the different programmes specific and distinct representations of science emerge (Machin 2007, Rose 2012). Focusing in detail on how each programme talks about and visually represents DNA, and the music and other soundtracks that is attached to these talk and visual sequences, will enable me to illustrate the different portrayals of science in each programme.

In *Wonders*, DNA is represented as easy to procure with household items. Once procured it is represented as revealing fundamental truths about what it is to be alive, which fundamentally alter human understanding of the world. In this portrayal science is certain, revelatory and all-encompassing. In *Bang* DNA is represented as an unruly substance. It requires a controlled environment, technical skill and equipment to procure. Even when subject to these controlled and skilled processes, DNA is represented as being able to defy expectation and require (re)interpretation. To understand DNA, a shared framework and standards are required. In this portrayal science is difficult, uncertain and subject to collective human standards.

I will look beyond the specific example of the contrasting representations of DNA to better understand the general representation of science in each programme. In *Wonders*, science provides a creation story that connects humanity to all of creation whilst locating humans at its pinnacle. In *Bang* science is an ambiguous endeavour that produces potential harms as well as potential benefits. To further show the general character of the representation of science in each programme, I will provide summary quantitative findings of the distribution of aspects of each programme's representation that was captured by the analytic coding categories. These findings show that *Wonders*' representation of science was religious, and overwhelmingly *Bang*'s was secular. I will show that the representation of science in these individual programmes was facilitated by their broadcast channel and time-slot, reinforcing the notion that televisual representations of science are a product of a network of institutional, professional and genre constraints.

Programmes Analysed

Wonders of Life

Wonders of Life is a series of five sixty-minute programmes presented by Brian Cox, Professor of Physics and Astronomy at Manchester University. The series was first broadcast in the United Kingdom in January 2013, on Sundays at 9pm on BBC Two. The series tagline, taken from the BBC website, describes the content as follows:

> "Professor Brian Cox explores the globe to reveal how a few fundamental laws of science gave birth to the most complex and unique feature of the universe - life." (BBC 2017b)

The programme is the third *Wonders* programme fronted by Professor Cox, following on from 2010's *Wonders of the Solar System* and 2011's *Wonders of the Universe.* The programmes see Professor Cox provide explanation of how life came into being, the processes which operate within living things and what defines what it is to be alive. To provide these explanations Professor Cox travels to various locations throughout the world; the Philippines, the USA, Africa and Madagascar, Australia and Mexico. Rather than travelling to laboratories or scientific field sites, Professor Cox is shown in the natural world, or amongst local lay people, as he provides his explanations. The argument of the film is progressed through the use of voice-of-god narration and presenter direct address, with occasional interactions between Brian Cox and local lay people.

Bang! Goes the theory

Bang! Goes the Theory is a short-format magazine series that aired between 2009 and 2014. Eight series of the programme were aired, with a total of sixtyfour half-hour episodes and three one-hour specials. The episodes sampled for analysis were from series 7, broadcast in March and April of 2013. This series was broadcast during the week between 7pm and 8pm on BBC One. Series seven contained eight thirty-minute episodes. The programme was hosted by a team of presenters; Maggie Philbin, Liz Bonin, Jem Stansfield and later Dallas Campbell. The tagline from the BBC website describes the content as follows:

> "Investigating the science behind the headlines and making sense of the everyday issues that matter to us all." (BBC 2017a)

"Bringing you the science behind the headlines" is a phrase often used by the presenters in the programmes' introductions. This indicates the programmes' focus on newsworthy and consumer-relevant science. It presents its content in typical magazine fashion, with a number of short sequences (videotapes or VT's in the language of the industry) which relate to a central topic which is the focus of that week's episode. These VTs include contributions from lab and field researchers as well as industry scientists. Reports from a scientific place of work, either a lab, field-site, factory or industrial workplace are common. The programmes also contain contributions from lay people who have questions or queries about some aspect of science or have relevant personal experience of a scientific or technological development.

Secular and Religious Portrayals of Science

Science is communicated in two distinct styles in these two science television programmes. I describe these different portrayals as 'Religious' and 'Secular'. A religious presentation does not need to reference God or Jesus, Buddha or Mohammed or any other figure of faith from an organised religion. A secular presentation is not secular because it references scientists or scientific theories. Representing DNA, gravity, evolution or any scientific topic does not automatically disqualify a programme from a religious presentation.

Each portrayal is characterised by the use of particular language, imagery and soundtrack. The religious portrayal presents scientific ideas as certain, unchanging, all encompassing (temporally, spatially and intellectually), revelatory (brute facts) and as able to provide meaning for the lives of those who believe them. When ideas are presented in this way, regardless of content, their portrayal is religious. The secular portrayal presents scientific ideas as uncertain and subject to change. Scientific accounts are not all-encompassing or necessarily superior to other understandings of the world. Scientific knowledge requires skill and expertise to produce. Its products can be either positive or negative, and there is no suggestion that scientific understanding can provide meaning. This kind of presentations is secular.

Table 12 reproduces the description of the representational devices or themes which make up the different portrayals. These themes were identified and developed through ethnographic content analysis (Altheide 1996).

RELIGIOUS PORTRAYAL	SECULAR PORTRAYAL
Creation Story: Science can, and already has, provided us with a definitive account of the creation of the universe and everything within it	**'An' not 'The' account of nature:** Science can provide us with one description of the natural world, without it being definitive or necessarily superior to others. Concurrently there are multiple scientific accounts of natural phenomena and disputes between them
Explanatory Omni-competence: Science can explain everything about the universe and the things within it. Any unanswered questions which currently remain will soon be answered	**"Further research is required":** Scientific knowledge is incomplete and cannot explain everything about the natural world. Ignorance is part of science and is a motivating factor within it. Discoveries raise as many or more questions as they answer. Scientific results can be more complex than initially expected
Revealed by Nature: Scientific truth or facts come out of nature with minimal intervention by humans. Scientific truths can be easily demonstrated away from laboratories in natural settings	**Technical Skill & Expertise:** Scientific truth or facts are difficult to produce and require technical skill and a particular setting – i.e. a lab – to produce. Expert communities are involved in the creation of scientific knowledge. Technological artefacts are important for creating scientific knowledge or doing science. There is a process by which scientific knowledge is extracted from nature or produced,
Immutable/Unchanging: Current scientific understandings are unlikely to change. Science has achieved a fundamentally correct understanding of the universe and the things which inhabit it	**Changeable:** Scientific understanding can and will change over time. Currently held scientific beliefs may be disproved in the future or by current research
Meaning Providing Endeavour: Scientific understanding can locate humanity within a grand universal narrative and thus provide us with existential justification and psychological consolation.	**Ambiguous Endeavour:** Science can provide humanity with both positives and negatives, whether they are understandings or physical artefacts or effects.

TABLE 12

There are two underlying strands to the secular and religious portrayals of science which can be contrasted. The issue of certainty is a key aspect of both these portrayals. In the religious portrayal, scientific knowledge is presented using the kind of language that is normally associated with revelatory truth. Scientific knowledge in this portrayal is definitive, its understandings correct now and forever. This is a dogmatic representation of science. Not only can it, but it is incumbent upon science, to explain everything about the universe;

physical, chemical, biological, psychological and social. Science here is presented as over-arching, total in its generality of explanation, rather than generalisable to a limited extent. Science can provide answers which can replace older, traditionally religious, answers to these fundamental questions of existence. In this way, science is presented as a force of nomisation, providing a shield from meaninglessness and justifying existence.

In the secular portrayal science is couched in terms of uncertainty. Scientific understanding is provisional, based on consensus and subject to change and revision. Science can explain particular things about the natural, physical, social or psychological world, but these explanations are partial, and the scientific project incomplete. Scientific understandings or theories do not provide the material for a grand narrative of creation.

The particular iconography that it utilised in the presentation of science is instrumental in rendering that portrayal either secular or religious. The location in which science is depicted as taking place; the specific tools, equipment, physical setting and number of individuals which are required to produce scientific knowledge contrast markedly in the different portrayals of science. Where scientific knowledge is represented as easy to produce, with little skill or technical equipment, without reference to the consensus of the scientific community in its production, it is being portrayed in a religious way. Scientific knowledge here is presented as revelatory; given to man by nature. It is divorced from the human context of its construction. In this way it is made to resemble scriptural wisdom as conceived by literalists; scientific knowledge is the 'word of nature' as scriptural knowledge is 'the Word of God'.

Alternatively, where scientific knowledge is represented as being difficult to produce, where complex procedures utilising specialist equipment are required, where shared standards have to be adhered to in order to produce scientific knowledge, the portrayal is secular. Here the human construction of scientific knowledge is evident and foregrounded. It is difficult and unpredictable, but eminently human. Scientific knowledge construction is analogous to other skilled, yet mundane, human activities.

The filmic imagery and soundtrack are also important in heightening the religiosity or secularity of the portrayal of science. The types of image selected and soundtrack used in different science TV programmes connote particular things, producing particular responses in their audiences. Imagery and musical soundtrack that seem to intend to generate a heightened emotional connection to the scientific content of a programme or to inspire awe in their audiences tend towards a religious portrayal. The connotative meanings of the imagery used in a programme also move it towards either a secular or religious portrayal. Imagery that has a traditional religious connotation will make the portrayal more religious.

What defines a portrayal of science as secular or religious is determined by the language used to describe science, the weight of certainty it is made to carry, the stated breadth of scientific knowledge and the suggested appropriate applications for it. Alongside this, the particular semiotic resources (both image and sound) that accompany these descriptions add to either the religiosity or secularity of the portrayal. This can be demonstrated through a detailed reading of the representation of science presented in the two programmes.

Quantitative Summary of Each Series

Two episodes from each programme were analysed quantitatively; episodes one and three of *Wonders* and episodes one and five of *Bang* (*Bang* was a 10 part series, which meant a coin was tossed to decide whether to analyse episode 5 or 6). It was assumed that the first episode would set the tone for the entire series and analysing it would provide a good understanding of the overall character of the series. The middle episode of each series was analysed alongside the first. The analysis of the middle episode was undertaken to assess whether the tone set in the first episode continued throughout the series. The continuity of the portrayal is important to assess. Boyce (2006) posits a model of accretion of public understanding over time. Boyce does suggest that this accretive effect can take a period of months or years to occur, and is emphasised if a scientific topic is the focus of a large amount of media attention (e.g. the MMR controversy). Nevertheless, a consistent portrayal is likely to be understood in consistent ways (Boyce 2006).

The analysis involved splitting each episode into a number of segments (of roughly 1 minute in length) and then analysing these segments in detail to see if they contained examples of either a secular or religious portrayal of science. The segments were unequal in length so as to allow for natural breaks in the films: cuts, ends of sequences etc. (this accords with Iedema's (2000) approach to content analysis.) How each episode was divided is shown in the following table

PROGRAMME/EPISODE	**NUMBER OF SEGMENTS**
Wonders EP 1	50
Wonders EP 3	52
Bang EP 1	28
Bang EP 5	28

TABLE 13

Each of these segments could contain examples of more than one element of the religious or secular portrayal. Some segments did not contain examples of either kind of portrayal. After close analysis, the following number of coded examples was recorded in each episode

PROGRAMME/EPISODE	**NUMBER OF CODED EXAMPLES**
Wonders EP 1	56
Wonders EP 3	81
Bang EP 1	40
Bang EP 5	33

TABLE 14

The results of this analysis are shown below:

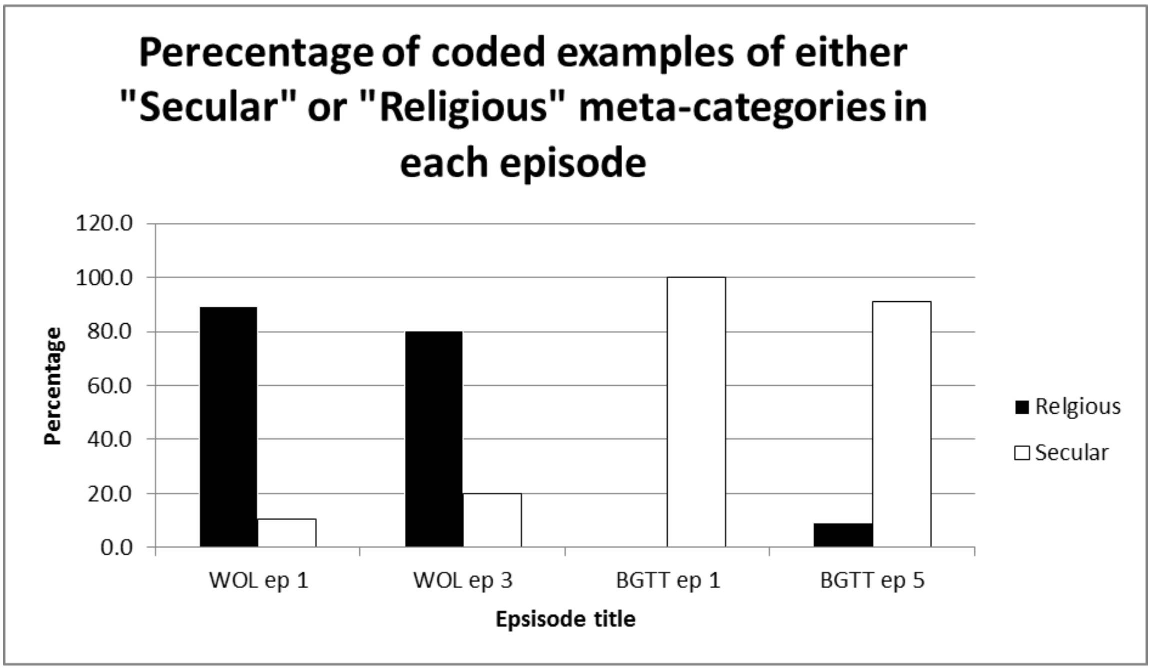


FIGURE 6

Fig. 6 shows that the 89% of the coded examples in episode one of *Wonders* were from the religious categories and 11% from the secular. 80% of the coded examples in episode three of *Wonders* were from the religious categories, and 20% from the secular. There were no examples from the religious categories in episode one of *Bang*, all of the coded examples came from the secular categories. 9% of the coded examples in episode two came from the religious categories, while 91% of the coded examples were from the secular categories. Aggregating both episodes together yields the following results;

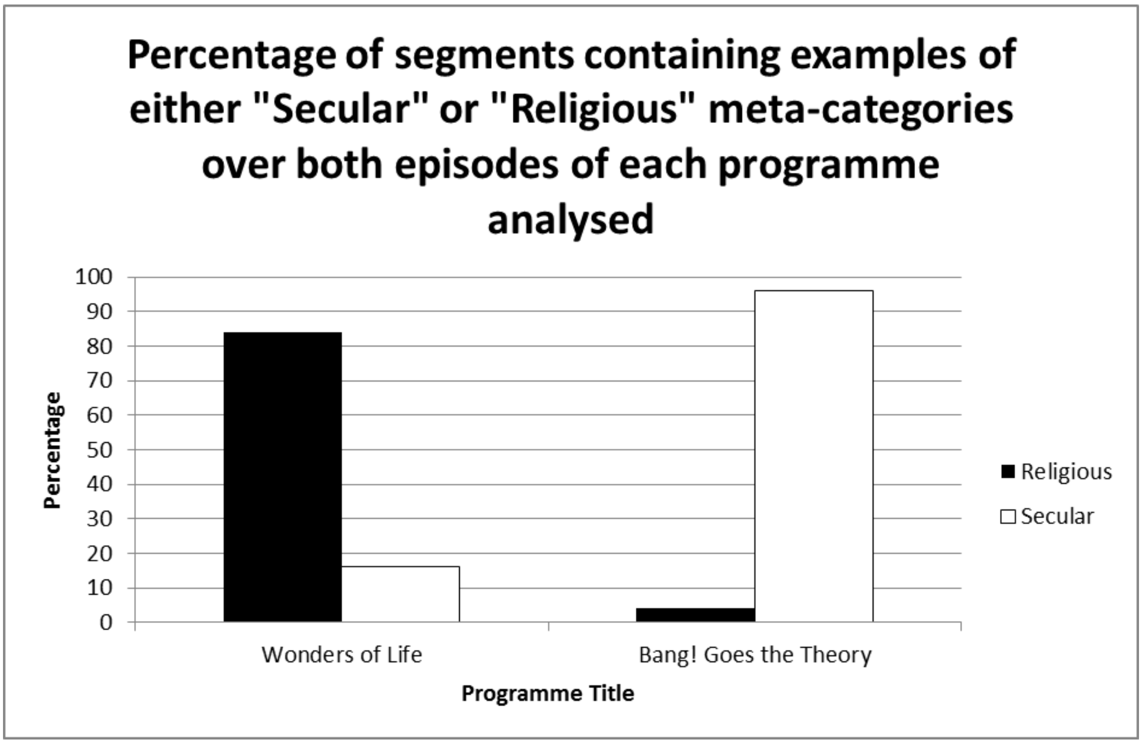


FIGURE 7

Fig. 7 shows that overall 84% of the coded examples in *Wonders* come from the religious categories, 16% from the secular categories. In contrast, only 4% of the coded examples in *Bang* come from the religious categories, while 96% come from the secular categories[34].

The Portrayal of DNA

The different portrayals of science are best illustrated through a comparison of how the same scientific topic is presented. It is not the specific scientific idea, theory, area or field that a programme focuses on that defines whether a portrayal is secular or religious. The differing portrayals of DNA in *Wonders* and *Bang* will illustrate this.

Episode one of *Wonders* and episode five of *Bang* contain sequences in which DNA is extracted and then interpreted. The setting in which the extraction

[34] See Appendix 4 for more detailed analysis of the distribution of each coding category in each episode.

takes places and the procedure for extracting DNA differ. The purpose of extracting DNA, and once extracted how it is interpreted are also distinct.

The Setting

Ep.1 47:26

Ep.1 47:30

The establishing shot of the *Wonders* DNA extraction sequence shows Brian Cox walking onto a wooden veranda and entering a building. This is filmed from an interior perspective, looking out, with Brian Cox approaching the camera, a heavily wooded, verdant background behind him. On the veranda are tropical looking shrubs. Brian Cox is wearing a loose fitting shirt and cargo pants and carrying a satchel. The setting appears to be hot and sticky like a jungle. The next shot is of the interior of the building he has entered. The building is an open plan bar area with dark wood and large open windows to either side. Brian Cox sits at the bar to the left of the centre of the shot and begins unpacking his bag.

This location is open to the elements, in a hot and humid environment. There is no specialist equipment, nothing traditionally associated with a scientific laboratory. As the sequence begins, there is little to suggest to the viewer that scientific work is about to take place.

The DNA extraction sequence in *Bang* is established with one of the presenters preparing a "mystery fish pie" in a kitchen. The task set by the presenter is for DNA analysis to identify the 6 different types of fish in the pie. To undergo this analysis, the pie is sent to "one of the top fish genetics labs in the country" introduced in the following shot;

Ep.5 03:15

The setting is very different from *Wonders*'. There is hi-tech equipment, shelves full of chemicals, beakers and flasks. Two men dressed in white lab-coats and protective blue gloves are shown unpacking the sealed container the fish pie is delivered in. The interior space shown being clean and hygienic, the men's coats and gloves and the use of the sealed container which isolates the fish-pie suggest the necessity of protecting against possible sources of outside contamination in order to complete the analysis. These establishing shots are followed by sequences which depict the extraction of DNA.

Bang Extraction Sequence (Ep.5 03:15-03:52 Screenshots)

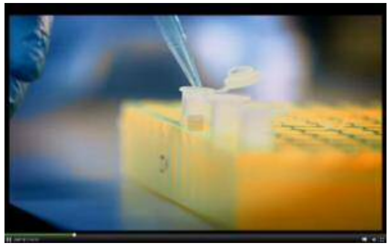
VO: at Bangor University.

Scientist on left: "OK, so, Mark, here we have the mystery fish pie."

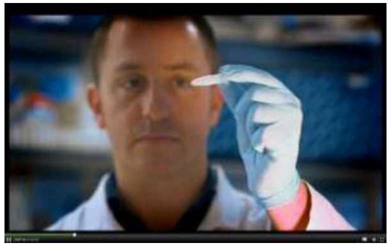
VO: The first stage of their analysis

is to extract and clean the fish

meat. The fish DNA

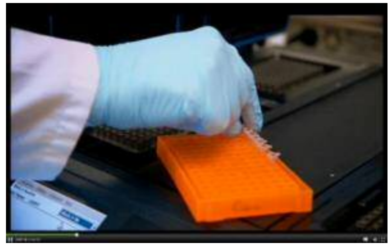


is extracted using ethanol



then a specific gene

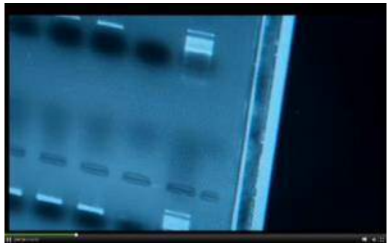
that's present in all fish is



pinpointed and using

PCR, a sort of

molecular photocopier, millions of copies of this



genetic bar code are made.

Wonders of Life Extraction Sequence (Ep.1 47:33-48:54 Screenshots)

Now, all I need to isolate my DNA is some washing up liquid, a bit of salt, and the chemist's best friend, vodka.

Now, to get a sample of DNA I can just use myself. If I just swill my tongue around on the edge of my cheek, I'll dislodge some cheek cells into my saliva.

I missed the test tube! There we are, a physicist doing an experiment.

Then I add a bit of washing up liquid.

Now, what this will do is it will

break open those cheek cells

and it will also degrade the membrane that surrounds the cell nucleus that contains the DNA.

Salt will encourage the molecules to

clump together

DNA is insoluble in alcohol

so you should get a layer of alcohol with the DNA molecules precipitated out.

Bang Extraction Sequence

The *Bang* extraction sequence takes place in a laboratory, as established in the opening shot. What follows from this establishing shot shows the use of a series of skilled techniques which transform an object of analysis to make it understandable in scientific terms. The fish pie is subject to a careful, intricate, skilled procedure. This first involves breaking the pie down into its constituent parts using precision tools. The resultant parts are then placed in a bottle of solution in order to extract the required substance (in this case DNA). The pieces of fish are then added to small vials and arranged in a tray. After this a scientist (whose white coat, blue protective gloves and presence in a lab are all indexical of his status as a scientist) scrutinises a vial to check its contents. This is followed by an extreme close up of the vial's contents, where a small piece of fish can be seen suspended in solution. The next stage of the process – the so-called 'molecular photocopying' of PCR - is not shown, but the output of this process is displayed on a computer screen. The output, described as "genetic barcodes" is a series of gradated black and white columns. The meaning of these columns, in and of themselves, is difficult to interpret for the untrained eye of the viewer. However, the visuals of the final shot suggests they are interpretable. The blue glove of the scientist is shown pointing at various parts of the genetic barcode on the screen, implying he is reading and understanding them.

Throughout this process, high-tech equipment is used by skilled practitioners in a controlled space. The process shows science to be a collaborative endeavour, with two scientists working to answer the question posed. The results of this process are not immediately interpretable to the untrained eye. The point of this complex process is to provide answers to a specific question, in this case, what kinds of fish are in this pie?

Certain depictions of laboratory spaces in television can actually present an idealised vision of science. This could be suggestive of a religious portrayal. A laboratory filled with bubbling flasks of colourful liquid is a common trope by which an audience recognises science on their televisions (Bell 2006). This trope is often reproduced by members of the public when asked to complete the 'draw a scientist' test (Chambers 1983). The connotation of this trope is that science is esoteric and mysterious. Science is a world populated by lone geniuses, of questionable sanity, scheming alone amongst their unfamiliar equipment (Pansegrau 2008). The lab is the cathedral were the science priest conducts his mysterious and unknowable rituals (Pansegrau 2008).

The portrayal of the mad scientist and portrayal of science in *Bang* differ. In *Bang* the laboratory contains technical equipment which is unfamiliar to the untrained eye and this equipment produces outputs that are difficult to interpret. Though the audience cannot interpret the outputs on the computer screen, it is clear that the scientist can. This alone may seem to reiterate some of the problematic representations described above. However, in using this specialist equipment and interpreting these outputs the scientist is attempting to answer a mundane question; what fish are in this pie? Though skilled, the work on display is analogous to other skilled practises. Complicated technical procedures are required to answer mundane questions. This real-world, mundane application keeps mystery to a minimum. The relationship between the mundane and the mysterious is reversed in *Wonders'* portrayal of science. Mundane equipment answers profound and mysterious questions.

Wonders Extraction Sequence

The *Wonders* extraction sequence doesn't take place in a laboratory. A dark-wood clad room in the jungle, which during the sequence is established as a bar, is the setting for *Wonders'* extraction of DNA. Brian Cox begins by outlining what he will use to extract DNA; washing-up liquid, salt, vodka and a sample of his own saliva and a test tube in which to combine these household ingredients. He spits in the test tube, then adds washing up liquid, to 'break open' the cells, salt to 'encourage the molecules to clump together' and then vodka, in which DNA is insoluble, resulting in the precipitation of DNA below the layer of alcohol. This sequence cuts between close ups of Brian Cox adding things to the test tubes and medium shots pulling closer to shots of Brian Cox's face talking directly to the camera.

As the establishing shot makes clear, extraction of DNA can take place anywhere. The process is simple and needs only commonly available household items. The ease with which this process can be completed is emphasised by the cup of tea on the bar alongside the 'experimental' equipment, and the persistent birdsong that is the soundtrack to this sequence. In *Wonders*' representation, scientific work requires no special location or skill to complete.

Though in this sequence a test-tube, an iconic symbol of science, is used, its familiarity adds to the sense that scientific knowledge can be revealed anywhere, by anyone. Anyone who has studied science at school has hands on experience of a test-tube. This representation of the extraction of DNA suggests anyone with access to familiar, everyday items can do scientific work.

The process of spitting into a test tube, adding unspecified amounts of vodka, salt and washing up-liquid can be successfully completed by anyone. This is very different from the skilled procedure shown in *Bang*, which shows the use of precision instruments and techniques and hi-tech equipment to transform fish pie into lines on a screen that require particular knowledge to interpret.

Both these extraction sequences are followed immediately by interpretation sequences. The interpretation sequence that follows the extraction sequence in *Wonders* shows that by combining mundane household ingredients in a test tube familiar to many, Brian Cox is able to reveal fundamental truths about the universe. In *Wonders'* representation of science the mundane provides access to the profound mysteries of the world.

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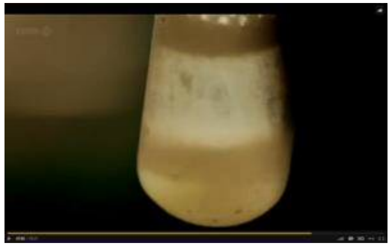
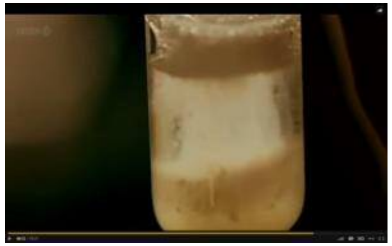
Wonders Interpretation Sequence (Ep.1 48:55-49:50 Screenshots)

“Yeah. There, can you see?



“Those strands of white. And so in that cloudy, almost innocuous looking solid are all

“the instructions needed to build a human being



“So that

“is what makes life unique”

VO: Only living things

have the ability to encode and transmit

information in this way

and the consequences

of that profoundly affect

our understanding of what it is to be alive

Wonders Interpretation Sequence

The interpretation sequence begins with Brian Cox looking closely at the contents of the test tube, before a close up reveals a white substance in the test tube bottom. This is followed by a cut to a close up of the test tube and then Brian Cox's face as he suggests that he is holding in his hands all the instructions needed to build a human being. An extreme close up of Brian Cox's face emphasises the importance of the information he is communicating as he states that DNA is what makes life unique. His statement is punctuated by the introduction of music, initially a woodblock or similar percussion instrument which adds further emphasis. Over the next visual sequence, the music becomes more prominent; the percussion builds and a stringed instrument provides accompaniment. This adds a sense of urgency and emphasis to what is said in voiceover, the contrast with the previous section which had no musical accompaniment alerting the audience to the importance of the current information. Visually, there is a cut to the beginning of a new sequence outside of the bar, with boots walking up a muddy, overgrown path. The sequence then cuts between close shots of plant and animal life and Brian Cox walking in the jungle. Over these shots, the voiceover explains that DNA allows life, and only life, to pass on information and that this "profoundly affects our understanding of what it is to be alive"

In the *Wonders* interpretation sequence, DNA is ascribed significant properties. In 48 seconds of screen time, the film suggests that Brian Cox has extracted all the information required to build a human being, the thing that makes life unique and something that fundamentally alters our understanding of what it is to be alive. The simple extraction procedure, accomplished using mundane, household objects in an everyday space has revealed a fundamental truth about the world. This truth has a profound impact on our understanding of our place in the world, it can not only tell us how life works, but explains what is to be alive. Furthermore, this understanding is uncontentious; DNA is the thing which makes life unique. This understanding *does* fundamentally alter our perception of existence. The connection of all living things is emphasised by the shots of various flora and fauna interspersed with shots of Brian Cox walking amongst them.

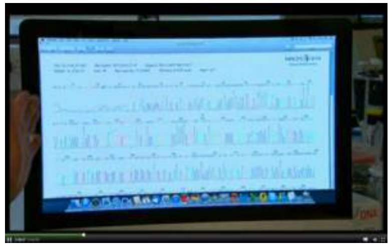
Bang Interpretation Sequence pt. 1 (Ep. 5 04:07-05:14 Screenshots)

MP: “I can’t wait to find out whether you’ve identified the fish in our pie”

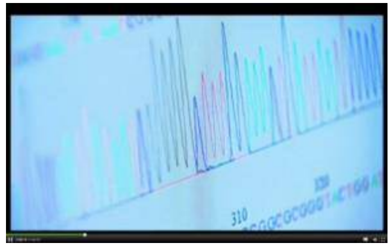
S: “Those mystery fish. Neither can I, I’m even more anxious thar you are!”

S: “OK, well, based on what we could see in terms of the colour and the texture of the chunks in the fish pie, we actually think we have six different species of fish.”

MP: “And that gets the first big tick, because, as you see on our fish chart, there are six species. But have you correctly identified them?”



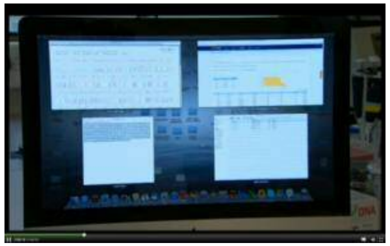
S: “When we get the data back



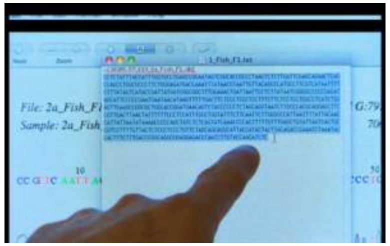
S: we have a trace of the sequences - ”

MP: so that’s one fish there, that’s - ?

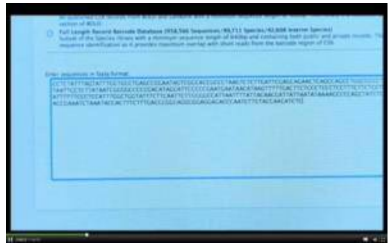
S: “This is the trace from one fish”



S: and essentially the DNA is an alphabet of just basically four letters



S: and it's the combination and the order of those letters that collectively



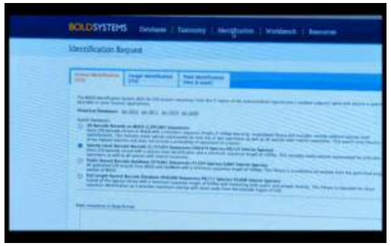
S: will tell us specific species. And over a third

S: have now been bar-coded

S: and they are in the reference database. So it means we can take our

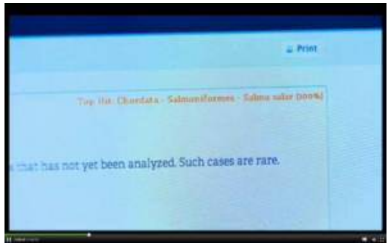
S: mystery unknown sequences,

S: drop them into the database and then search for a match



S: So what it is telling us, with a very high level of certainty, it's telling us that

S: the first piece of tissue that we extracted DNA from belongs



S: to Atlantic salmon.

MP: Ta-da!

S: We have an Atlantic salmon! Very good, very good

Bang Interpretation Sequence pt.1

The first part of the *Bang* interpretation sequence reveals the initial results of the investigation into the mystery fish pie. The sequence begins with the presenter Maggie Philbin conversing with one of the scientists, Dr Mark Carvalho, involved in the fish-pie analysis (he is seen at the beginning of the extraction sequence delivering the fish pie to the scientist who extracts the DNA). A shot outside the lab looking in through the windows carries the initial conversation.

The conversation starts with Maggie Philbin saying: "I can't wait to see if you've identified the fish in our pie" and Dr Carvalho responding: "Me neither, I'm even more anxious than you". This admission of doubt and uncertainty can be contrasted with Brian Cox's suggestion that he is holding in his hands all the instructions needed to build a human being. In *Bang*, the hi-tech procedure in the controlled laboratory space still leaves room for doubt and uncertainty. The facts revealed in the bar in *Wonders* are unquestioned.

The sequence continues with Dr Carvalho suggesting there are 6 different species of fish in the pie, which Maggie Philbin confirms. He then describes how the different fish are identified. This process involves taken the computerised DNA sequences and 'dropping' them into a database of fish species. Shots of computerised outputs; sequences of letters being put into a search field on what we assume is the database homepage and a result being outputted are presented. During this visual sequence Dr Carvalho explains how over one third of the world's species of fish have so far been categorised. This subtly reiterates the notion that science is an ongoing process. Two-thirds of the world's fish species are yet to be catalogued. Scientific knowledge is far from complete. The use of computerised equipment and international databases show science to be a hi-tech, resource specific and collaborative endeavour.

The computer screen output shown matches Dr Carvalho's claim, made with 'very high certainty', that the first fish they have identified is salmon. This is then confirmed by the presenter Maggie Philbin, who uncovers a picture of a salmon on her sticker board prop. This process then continues in much the same way for the next three fish in the pie, with each time the scientist ending up at the correct result through his sequencing procedure.

During the initial interpretation sequence, where the scientist is shown to get the correct answers to the questions proposed by the presenter, doubt, uncertainty and gaps in knowledge are all communicated. Even when the scientist is sure of an answer, he only has very high, rather than complete certainty in his findings. The making of scientific knowledge is shown to be skilled, require specific tools and access to specific resources and a specific community. These aspects of science are further emphasised in the next parts of the interpretation sequence.

Bang Interpretation Sequence pt. 2 (Ep. 5 05:39-06:24 Screenshots)

S: “OK. Now, with the other two

S: “we had difficulties in terms of the quality of the sequence

MP: “OK”

S: So, one of them we actually

S: “thought was not a very good-quality sequence”

S: “Visually, when we took it from the pie,

S: “it looked to us like it could be catfish, Vietnamese catfish, otherwise known as river cobbler.

S: “But we had it sequenced alongside all of our other samples,

S: “and it came back as a bacterium.

S: “So it can actually, of course, indicate poorly stored fish.

S: “When we think about Vietnam, it's a long distance away

S: “and the likelihood is of course that for part of that

S: “or periods of that, the fish may have been stored above freezing for quite some time.

MP: “Well, let's just see if you're correct. And it is indeed

MP: “River cobbler

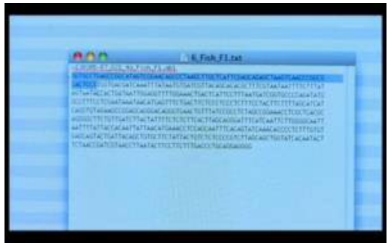
Bang Interpretation Sequence pt. 2

Visually this part of the interpretation sequence is similar to the preceding section. It shows Maggie Philbin and Dr Carvalho in conversation from 3 different angles, a shot of each individually and a wider shot with both in the frame alongside the fish sticker-board prop and the computer from which Dr Carvalho is reading his results.

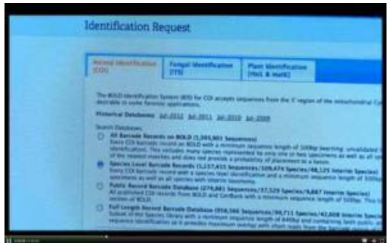
However, in this latter part of the overall interpretation sequence Dr Carvalho discusses some of the problems faced during the analysis of the mystery fish pie. He suggests that the DNA sequence of one of the fish species was not ‘very good quality’. This leads to a discrepancy between the visual appearance of the fish and the results of the DNA extraction. Dr Carvalho explains the fish looks like catfish but the sequence returned by the database is a bacterium. He goes on to offer some possible explanations for this; poor storage of the fish and the long distances involved in transporting it. Maggie Philbin then confirms the fish is river cobbler.

This sequence shows how hi-tech and skilled procedures still produce results that are difficult to interpret, or that run counter to expectations. Dr Carvalho cannot rely on DNA sequencing alone; the output it has provided is unsatisfactory for answering the question with which he has been posed. To answer this question, he must weigh the DNA evidence with other factors to come to a satisfactory conclusion. This representation of a nuanced interpretation of an unruly sample is very different from the interpretation of DNA presented in *Wonders,* where everyday objects in an everyday space have revealed a timeless and universal truth. This theme of uncertainty and difficulty of interpretation is continued in the third part of the extraction sequence.

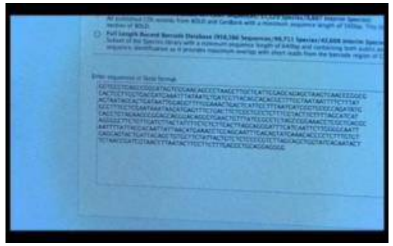
Bang Interpretation Sequence pt. 3 (Ep.5 06:53-07:24 Screenshots)



MP (VO): The identity of the last species wasn't clear from the first analysis



MP (VO): but a routine second test did confirm the result.



S: "The quality of the sequence is not up to our usual standard, but we do have pretty high certainty that it

S: "was monkfish

S: based on

S: "re-sequencing it more than once.

MP (VO): A retest also

MP (VO): confirmed the river cobbler, complete with bacterial

MP (VO): contamination, giving Dr Carvalho an impressive six out of six.

Bang Interpretation Sequence pt. 3

Problems with identifying the sixth species of fish are discussed by Maggie Philbin in the voiceover. An image of the fish database home page is shown, followed by a shot of a sequence of letters being inputted into a computer search field. Over these images, Maggie explains that the initial sequencing did not produce a result that could be used to identify the species of fish. She then goes onto say that a "routine second test" confirmed the result. Describing multiple testing as routine reinforces the idea that in the process conducting scientific research, it is normal for tests to produce unclear results which are often difficult to interpret.

Dr Carvalho is then shown explaining that "the quality of the sequence is not up to our usual standards, but we do have pretty high certainty that it was monkfish". This shows that science is subject to communal, human standards, another aspect of the secular portrayal. The claim that the sequence "doesn't match up to our standards" suggests there is a communally defined agreed upon level of quality which must be met during scientific processes in order for reliable scientific knowledge to be produced. Due to the fact that the sequence did not meet these standards, Dr Carvalho is only able to say that he has "pretty high certainty" about the identity of the monkfish. He further emphasises the point that the DNA has been sequenced multiple times to arrive at this conclusion.

That repetition of tests is routine during scientific research is reinforced by the voiceover in the final shots of the sequence. Maggie Philbin states that following a further re-sequencing of the troublesome sample, the DNA sequence aligned with the visual evidence, allowing the scientists to eventually conclude that the fish was river cobbler.

Beyond DNA: Further Illustration of the Secular and Religious Portrayal

Other elements of the secular and religious portrayals are less apparent in the DNA extraction and interpretation sequences but are identifiable elsewhere in the programmes. Both the creation story and explanatory omni-competence aspects of the religious portrayal can be seen in the closing sequence of the episode one of *Wonders*. This sequence also presents science as certain and as providing meaning. The emotive consequences of scientific understanding is particularly heightened by the use of music within the sequence.

Wonders Ep.1 Closing Sequence (Ep. 1 56:41-60:10 Screenshots)

BC: “And you could carry on all the way back in time. You could look for our common ancestor with a chicken, and you'd find that our codes are about 60% the same. And in fact, if you look for any animal, like him, a little fly, or a bacteria, something that seems superficially completely unrelated to us, then you'll still find sequences in the genetic code which are identical to sequences in my cells.”

BC: “So this tells us that all life on Earth is related, it's all connected through our genetic code.”

Music starts – slow strings counterpointed with plucked strings/harp, peaceful and dreamlike

BC (VO): DNA is the blueprint for life

Music continues, now accompanied by female choral singing and slow whooshing sound effect to match revolution of DNA and its moving up the screen

BC (VO): but its extraordinary fidelity

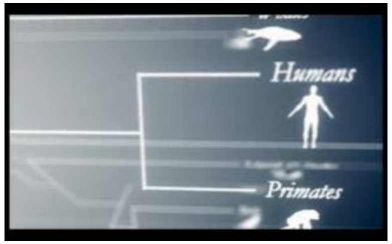
BC (VO): means it also contains a story, and what a story

Whooshing subsides, music continues, more gentle

BC (VO): it is

BC (VO): the entire history of evolution, from the present day

Singing more prominent now in music



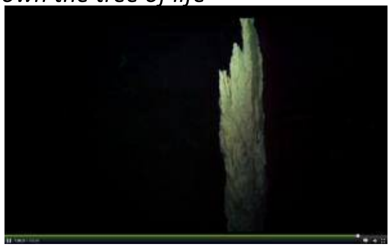
BC (VO): all the way back

Whooshing returns as we travel back down the tree of life

BC (VO): to the very first

BC (VO): spark of life

BC (VO): And it tells us that we're connected, not only to every



BC (VO): plant and animal alive today

BC (VO): but to every single thing that has ever lived

Music more rousing now, strings more prominent more drive and rhythm to the music

Choral singing more prominent now, music building

Drums enter, violins now playing a more prominent melody over other strings and singing, music building all the time

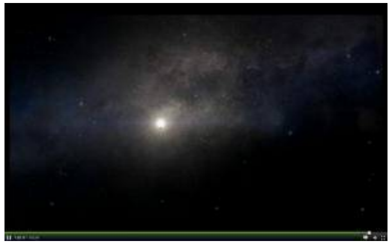
Music reaches crescendo with choral singing, then begins to fade-out

BC: “The question, what is life

BC: "is surely one of the grandest of questions, and we've learnt that life isn't really a thing at all. It's a collection of chemical processes that can harness a flow of energy to create local islands of order, like me and this forest, by borrowing order from the wider universe and then transmitting it from generation to generation through the elegant chemistry of DNA. And the origins of that chemistry can be traced back four billion years, most likely to vents in the primordial ocean. And, most wonderfully of all, the echoes of that history, stretching back for a third of the age of the universe, can be seen in every cell of every living thing on Earth."

BC: "And that leads to what I think is the most exciting idea of all, because far from being some chance event ignited by a mystical spark, the emergence of life on Earth might have been an inevitable consequence of the laws of physics. And if that's true, then a living cosmos might be the only way our cosmos can be."

Sound of waves lapping, then howler monkey call, before music starts; guitar playing intro to galaxy song from Monty Python's the Meaning of Life



Lyrics begin as credits roll, behind credits CGI shots of space, zooming out from our solar system to see whole galaxy

'Just remember you're a tiny little person on a planet, In a universe expanding and immense;
That life began evolving and dissolving and resolving, In the deep primordial oceans by the hydrothermal vents;
Our Earth which had its birth almost five billion years ago, From out of a collapsing cloud of gas;
Grew life which was quite new and eventually led to you, In only 3.5 billion years or less.'

Creation Story and Provision of Meaning in Wonders Ep.1 Closing Sequence

The sequence begins with Brian Cox in a sunlit rainforest clearing. To camera, he outlines how all life is connected through DNA. A cut to a CGI image of the double helix of DNA, is followed by a shot of an indri lemur, then a land crab and finally an aerial shot of a herd of wildebeest. These images visually illustrate the claim that "all [life is] connected through our genetic code". The music accompanying this sequence is strings and choral singing, adding a dreamlike and reverential quality to the sequence. The music builds throughout the sequence, adding emotional force to the images and voiceover.

During this sequence, the voiceover reiterates that DNA is the 'blueprint for life' but more than this, it suggests that DNA contains the story of the entire history of evolution. A lengthy CGI sequence begins with an image of the 'tree of life', with an iconic representation of a human body at one end. The sequence moves back through time, down the tree of the life, as indicated by the passing of year markers signposting the journey into the past. As the end of the tree is approached an image of a fuzzy circle appears, described in voiceover as 'the first spark of life'. CGI gives the impression of travelling into and through this fuzzy circle, which with a flash reveals an image of floating spheres. These resolve into an image of what look like bacterial cells; unevenly shaped cylinders connected together. The CGI sequence ends with a cut to a shot of a white structure against a black background, which is used earlier in the episode and is recognisable as an undersea thermal vent. This then fades into another CGI image, of brown shapes slightly pulsing inside some kind of white structure. This is another image used earlier in the episode to represent the first cellular life appearing inside small crevices within the undersea hydrothermal vents. The voiceover of this sequence reiterates the connection DNA provides to all the things that have ever lived. The visual narrative supports this and provides a visual account of the very beginnings of life and its direct connection to humanity.

The creation narrative is clear in this sequence. In the earlier sequence where the hydrothermal vents first appear, they are offered as a possible candidate for the location of the genesis of life on earth. In this final sequence the uncertainty is absent. The hydrothermal vents are visually located in a certain and complete narrative from the present day to the temporal and spatial origins of our own, and all life's, creation. This creation story explains the origins of life with the kind of certainty associated with religious revelation. It states how, when and where life was created, definitively.

This interconnectedness of all life is reinforced in the next part of the sequence. In so doing, it reinforces the idea that scientific understanding can provide meaning. The visuals and musical soundtrack of this part of the sequence create this effect. These visuals and soundtrack provide the opportunity for the audience to marvel at the connection we have to all life, and be simultaneously emotionally stimulated, awed and existentially justified by the understanding science provides.

A shot of trees in a forest filmed vertically from the forest floor is followed by a close up image of a small insect on moss. Visually this connects living things, in all their forms, from largest to smallest. This is followed by a visual comparison of life's complexity. A shot of the eye of an undersea creature is followed by a shot of mushrooms. The eye here is a symbol of the complexity of life and the mushrooms represent life's beautiful simplicity. During this visual sequence the soundtrack builds with the introduction of drums as the choral singing and violin melody reach crescendo. After this crescendo, the music fades and there is a cut to Brian Cox sitting on a lakeside pontoon. The piece to camera he delivers emphasises science's meaning providing ability. The shot begins as a wide shot, before moving in to a mid-shot, a more intimate shot which emphasises the importance of what is said by Brian Cox. To camera he states that "the emergence of life on Earth might have been an inevitable consequence of the laws of physics". Though this statement is couched in more uncertain terms than are used elsewhere in the programme, this uncertainty is quickly counterbalanced by the lyrics to the end credit song. Eric Idle sings a reworked version of *The Galaxy Song* from *Monty Python's The Meaning of Life.* This song, though originally and intentionally comedic, provides a definitive account of the creation of life, the universe and everything within it. In this account human existence is not contingent, but necessary. Scientific understanding anticipates humanity's existence, providing existential justification through the knowledge that humans were meant to be.

Explanatory Omni-competence

The explanatory omni-competence of science is visible towards the end of this final sequence and in various other places during the episode. During Brian Cox's pontoon based piece-to-camera, he explicitly and definitively states what life is; "Life isn't really a thing at all. It's a collection of chemical processes." Any other definitions of what life is are discounted in this explanation. Science explains what life is. It shows when and where life appeared, and reveals that life, in all its different contemporary and historical forms, is connected through a product of scientific enquiry, DNA. In an earlier sequence in the episode, Brian Cox visits a graveyard in the Philippines during a religious festival honouring the dead. With this as a backdrop, he makes the following statement:

> "I mean, if we are to state that science can explain everything about us then it's incumbent on science to answer the question what is it that animates living things, what is the difference between a piece of rock that's carved into a grave stone and me?" (*Wonders* Ep. 1, 07:20-07:38)

This most explicitly reveals the explanatory omni-competence theme. Brian Cox here states that science not only *can* explain everything about us, it should do so.

"Further Research is Required"

Scientific research being represented as a constant process of finding new things out is identifiable in episode one of *Bang*. The presenter Liz Bonin travels with ocean scientists on a small research vessel as they explore the effects of plastic on ocean life. In response to Liz Bonin's questions about the impacts of micro-plastics, one of the scientists states:

> "Well that's really one of the great unknowns and it's, it's something that we're really trying to establish and some of the research that we're doing at Plymouth is what is the potential harm from these microscopic fragments of plastic in the environment." (*Bang* Ep.1, 15:11-15:22)

Scientific knowledge here is incomplete. The scientific process is geared towards establishing new knowledge, but many questions remain unanswered.

A representation which contrasts directly with the explanatory omni-competence device can be identified in a sequence in *Bang* immediately after the DNA extraction and interpretation sequences outlined previously. The presenters of the programmes are filmed walking through a market and being given a burger to eat. Liz Bonin, one of the three presenters of the programme, gives the following piece to camera:

> "So that's good news for fish eaters, but you do have to wonder why this technology wasn't used to avoid the horsemeat scandal. But the thing is fish testing is very different to meat testing, in meat testing you're looking specifically for cross contamination with other farmyard meats, so you're looking for the DNA of lamb and beef and pork and poultry, but not for the DNA of horse, it was only after a tip off that they went looking for it and unfortunately found it" (*Bang,* Ep. 5, 08:28-08:55)

This quote shows how the scientific process is not solely able to explain everything about the world. Scientists can attempt to answer the questions they are presented with. If the right questions are not asked then science is not helpful. This is very different from representing science as able to explain everything about the world.

Ambiguous Endeavour

Throughout both episodes of *Bang* there are a number of examples of the results of the scientific process being ambiguous, in that they are potentially damaging or unknown. One of the clearest of these comes in the first episode analysed, which focuses on the use of plastic in the modern world. A sequence shows a family discussing some of their worries about plastic use. They are then tested for their exposure to different plastics and subsequently reassured by the presenter Maggie Philbin that there are extremely low health risks posed by their plastic use. However, this is followed by a sequence which complicates this picture.

Bang Ambiguous Endeavour (Ep.1 21:13-23:20 Screenshots)

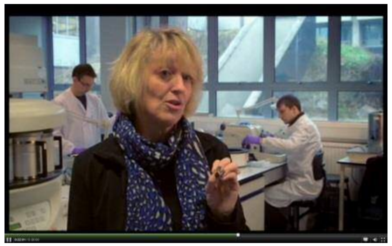
MP: "The two types of chemical that we looked at with the Nathaniel's have been well studied, and shown to be safe at the levels to which we are normally exposed. Since we made the film, a new report from the World Health Organisation, and the United Nations environment programme has hit the headlines. I caught up"

MP: "with one of the authors to discuss the findings

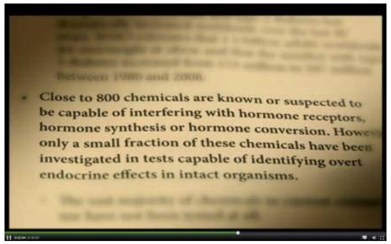
SJ (scientist): "So the report summarises the results of

SJ (scientist): "over a decade of work on endocrine disrupting chemicals. These are chemicals which interfere with or mimic the action of hormones and in so doing cause adverse effects on bodily functions."

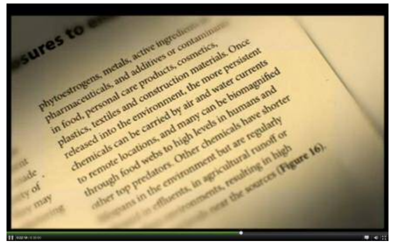
MP: ""Are we likely to be exposed to levels of these chemicals which could have an adverse effect?"



SJ: ""There are 143,000 chemicals in commerce

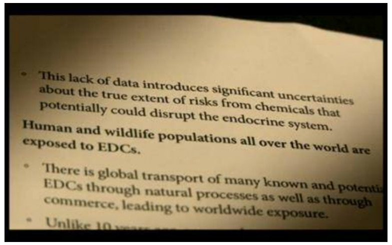


SJ: "and of those currently we know there are about 800 which may be endocrine disrupting chemicals"



SJ: "these chemicals are everywhere, they're in our food, they're in our furniture and they're in cosmetics. What this means

SJ: "is that we experience exposure to diverse chemicals from various sources as a cocktail and that whilst individually these chemicals may not cause harm collectively they may have already reached harmful levels"

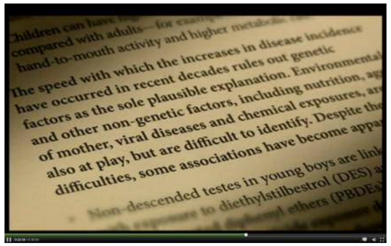


SJ: "many diseases and disorders in modern day society that"

SJ: "are endocrine disorders such as reproductive cancers, like prostate"

SJ: "and breast have risen over the last forty to fifty years "

SJ: "and that this rise has been too steep and too fast"



SJ: "to be explained by genetics alone. Environmental factors are generally accepted to be involved"

MP: "It's not hard to see just how complicated this is. On the one hand you've got exposure to a vast number of chemicals and effects on the body that might take decades to manifest themselves. It's clear that much more research is needed and in the meantime we have to weigh up the potential risk against the very real benefits that plastics can offer."

This sequence shows how the products of science are unpredictable and can have possibly harmful effects. The sequence focuses on the effect certain plastics in combination may have on the human body. The sequence sees Maggie Philbin visit a female scientist in a lab and discuss the findings of a new report. The shots of Maggie and the scientist are intercut with close ups of text in the report. The final shot of the sequence sees Maggie deliver a piece to camera outlining the possible problems caused by these plastics, but suggesting that more research is required, and that in the meantime a balanced approach needs to be taken when weighing the harms against the benefits of plastic use.

This sequence exposes the audience to various scientific technologies. These include the physical spaces of the laboratory, the material objects used within them, but also the literary technologies of science through the use of close up of the text of the scientific reports Maggie Philbin is discussing with the scientist.

Science is once again portrayed in a communal way. Shots of white-coated men working in a laboratory are the backdrop to the discussion between Maggie Philbin and 'one of the authors', Professor Susan Jobling, of a new report. This sequence also emphasises science's changeability. This is a new report that contradicts or raises new questions about what was previously known. Science is shown to be far from straightforward, it deals with complex phenomena which are not easy to explain; there are "vast numbers of chemicals" whose "effects on the body might take decades to manifest themselves". Science is also represented as providing explanations that are provisional rather than definitive, and defined by consensus. The chemicals under study '*may* cause disruption' and are an environmental factor that are '*generally accepted* to be involved' in a rise in cancers.

Though this sequence suggests that the products of science can cause potential harm, it also suggests that the most appropriate way to alleviate this harm is through further scientific effort. Scientists are best positioned to understand how this harm can be ameliorated. Furthermore, the possible harms have to be weighed against the 'very real' benefits provided by plastic, showing how complex risk decisions are required by the individual and society in order to navigate through a modern, technologically advanced society. This can be contrasted with clear and definitive solutions laid down by an all-knowing science which is presented in the religious portrayal.

The Religious Portrayal in *Wonders*: The Significance of Revelatory Ambivalence

Alongside the characteristics of the portrayal which I have described as pertaining to religion in general – the creation story, the totalising framework for understanding and explaining the world, the provision of meaning, and the certainty of (some core of) belief – the way in which scientific knowledge is 'revealed', and to whom, in *Wonders*' portrayal of DNA aligns more with certain religious groups understanding of revelation than others.

In the DNA extraction and interpretation sequence in *Wonders*, scientific knowledge is represented as revealed not only to a chosen few, but to anyone who desires access to it. Portraying scientific knowledge as revealed in this way aligns with a sub-set of religious understanding of revelation. For example, the Lutheran concept of the 'universal priesthood of all believers' (Luther 2009, p. 407) is a foundational concept of protestant theology which sees all Christians as being granted direct access to God through Christ. Baptism grants all Christians equal access to God; there is no divide between "spiritual" (priestly) and "secular" (lay) Christians. Any baptised Christian can have direct access to, and interpret, the divine. No intermediary (i.e. a priest/the priesthood) is required.

In *Wonders'* DNA sequence, the production of scientific knowledge is presented in this way. Anyone has the ability to access and produce scientific knowledge. In the case of the Lutheran the intermediary bypassed was the catholic priesthood. In *Wonders*' portrayal the input or mediation of intermediaries to the natural world i.e. the scientific community is not required in order to ascertain fundamental truths about the world.

A contrasting portrayal, which could align more with, for instance, catholic understandings of revelation, could be envisaged. Here science would be represented as certain, providing a creation story, explaining all aspects of life and providing meaning, but scientific knowledge would be handed down by a priestly caste of scientists. This knowledge would be the product of the science-priests' interpretation of the natural world, a world to which only the science-priest has real access. This access to nature and subsequent interpretation would produce certain knowledge, the context of its construction veiled in mystery.

This kind of portrayal is also identifiable in *Wonders.* Immediately following the grave-side sequence at the beginning of episode 1, a sequence begins with Brian Cox in a café summarising Erwin Schrodinger's book *What is Life?* Cox provides the following summary:

> "In February 1943 the physicist Irwin Schrodinger gave a series of lectures in Dublin. Now Schrodinger is almost certainly most famous for being one of the founders of quantum theory but in these lectures, which he wrote up in this little book he asked a very different question, *what is life*? And right up front on page one, he says precisely what it isn't, it isn't something mystical, says Schrodinger, there isn't some magical spark that animates life, life is a process, it's the interaction of matter and energy described by the laws of physics and chemistry, the same laws that describe the falling of the rain or shining of the stars." (*Wonders*, Ep. 1, 09:30-10:14)

Representing science in this way is much more akin to the catholic portrayal described above. Schrodinger has interpreted the world and provided explanation for it. How this explanation was arrived at is of no concern to the lay audience. Answers to the fundamental questions of existence are provided by scientists interpreting the world, and these are the only legitimate explanations of phenomena.

That scientific revelation is represented in this ambivalent way further emphasises the religious character of *Wonders*' portrayal. Specific religions have specific understandings of revelation. Religion as a general social phenomena exhibits an ambivalence towards the concept of revelation; the mechanisms by which it occurs and who can legitimately access and interpret religious knowledge. *Wonders* reflects this revelatory ambivalence. Though in its portrayal of science, *Wonders* represents scientific revelation in a seemingly contradictory way, this contradiction is present in the general social category of religion. This serves to further justify the designation of *Wonders* portrayal of science as an *in general* religious portrayal of science.

The Influence of Form on Content

Wonders is an hour long documentary broadcast at 9pm. At this time and in this genre the demand for a clear, definitive narrative must be satisfied, and to compete with progammes on other channels the images must be of a requisite aesthetic quality. In satisfying the demand for a clear, definitive documentary narrative, science comes to be represented as clear and definitive. At the start of the episode, Brian Cox poses the question "What is life?" This is the title of the episode, and providing an answer to this question becomes the central theme around which the narrative of the episode is organised. As the closing sequence of the episode detailed above shows, to answer this question in a televisually appropriate way, to satisfactorily close the narrative, a definitive answer is provided; "life isn't really a thing at all, it's a collection of chemical processes…" The use of closed-from narratives to engage an audience facilitates representing science as certain and definitive, a fundamental aspect of the religious portrayal of science. This format, in its use of beautiful images which stimulate the emotions of the audience, emphasises other aspects of the religious portrayal. Showing Brian Cox conducting 'experiments' in beautiful natural locations suggests that science can be carried out anywhere, by anyone, representing scientific knowledge as being revealed by nature. In the closing sequence, the visual imagery is enrolled to support the creation story which is delivered in the talk of the programme. In concord with the soundtrack, these images add to the sense that science provides a narrative that connects humanity to all living things, and justifies our existence.

Bang as a magazine programme broadcast between 7pm and 8pm utilised different techniques of engagement, which facilitate a more secular portrayal. The demand to include a definitive narrative is less apparent, due to the nature of the time-slot audience. This limits the opportunity for the representation of science as certain as the demand for narrative certainty is less keenly felt.

Bang attempts to engage through the relevance of its content to its audience daily lives, by bringing its audience 'the science behind the headlines'. *Bang*'s quest for relevance means it focuses on more topical scientific issues, or on the functional application of science. The episode in which the fish-pie DNA extraction sequence occurred focused on food safety, and was broadcast in the wake of the 'horse-meat scandal' (a scandal where a range of super-market food suppliers were identified as providing various meat-based products contaminated with horse-meat). Representing science as being able to provide solutions to problems of food safety connects science to worldly issues. The kinds of solutions science can provide are not definitive, even when produced by skilled experts.

The format and time slot in which *Wonders* and *Bang* were broadcast provide some explanation for their different representations of science. A long-form documentary broadcast at 9pm engages its audience through closed-ended storytelling and beautiful imagery. These devices facilitate a religious portrayal of science. A magazine programme broadcast between 7pm and 8pm cannot tell the same kind of stories. Its focus on relevant and topical applications of science mean it shows science in relation to the everyday world, providing indefinite solutions to mundane questions. This facilitates a more secular portrayal of science.

Conclusions

Overwhelmingly, *Wonders* employs a religious portrayal of science and *Bang* employs a secular portrayal. This has been illustrated in detail through the ways in which these programmes portray DNA.

In *Wonders,* DNA is easy to reveal. It is possible for anyone to extract DNA using everyday household items in an everyday environment. However, this simple process can produce a substance that has incredible properties. It connects all of life, makes life unique in the universe, defines how life is created and what it is to be alive. Its ability to do this is not contentious in anyway; DNA definitively does all these things. Through our scientific understanding of DNA our perceptions of what it is to be alive, the very fundamentals of existence, are altered in profound ways. Science can explain our creation and locate us within this universal narrative through DNA. This portrayal of DNA and the scientific process more generally is religious.

In *Bang,* DNA can be used to answer specific, mundane questions; questions surrounding food contamination and specifically the identity of species of fish in a mystery pie. In order to answer these specific questions a complex, technical procedure needs to be carried out by "experts" in "top labs" who utilise specialised equipment in a controlled space. This complex procedure produces answers about which the experts involved have pretty high levels of certainty, most of the time. The process, though carried out by skilled experts, may need to be repeated in order to produce results that are deemed satisfactory. What counts as satisfactory is a communal, human judgment and the results of the technical process are interpreted and assessed based on these standards. This portrayal of DNA and the scientific process is secular

Though in the *Bang* DNA extraction and interpretation sequence the scientists eventually arrive at the correct answer to the question asked, the way in which the answer is arrived at, and the kind of certainty attached to the answer is vastly different from that in *Wonders*. The substance Brian Cox produces in his jungle bar, with his mundane, household objects reveals essential truths about the universe and fundamentally alters our perception of existence. The substance produced by experts in the top fish genetics lab in the country can only be used to successfully identify four out of six fish in a pie at first time of asking. In each programme this substance is DNA, but the contrasting portrayals render DNA in one programme unrecognisable from DNA in the other.

Other sequences in the programmes reinforce the religious and secular portrayal. Scientific understanding in *Wonders* is total, omni-competent, and should aspire to be so. This complete understanding provides a definitive creation story, justifying our existence and rendering life necessary. Scientific understanding in *Bang* is incomplete; many questions remain to be answered. The products of scientific enquiry can be positive, but can also cause potential harm. Science can provide some guidance on how to navigate a modern, technologically advanced world, but this guidance will not be definitive, nor will it provide the justification for existence that *Wonders'* science will.

As I have shown in the previous chapter, these programmes will be designed to serve an audience. The content of these programmes, the way in which science is represented, will be defined in relation to the specific audience they intend to engage. This suggests that there is a sizeable audience for science presented as certain, definitive, as providing a creation story and as justifying human existence. *Wonders* received between 2.2 and 2.4 million viewers per episode at 9pm on Sunday evening. These millions of viewers were all exposed to and engaged by a religious portrayal of science. The potential impact this portrayal has on its audience requires exploration. Is it plausible that the religious portrayal of science performs a religious function for its audience? What are the implications for public understanding of and engagement with science, and for society in general, if science is perceived of and engaged with as a religion? In the remainder of the thesis, I will address these questions.

CHAPTER 7
"CREATION TALES FOR ATHEISTS"
THE RELIGIOUS FUNCTION OF THE RELIGIOUS PORTRAYAL OF SCIENCE

> *"A religion old or new, that stressed the magnificence of the universe as revealed by modern science, might be able to draw forth reserves of reverence and awe hardly tapped by the conventional faiths. Sooner or later such a religion will emerge."*
>
> CARL SAGAN, *PALE BLUE DOT: A VISION OF THE HUMAN FUTURE IN SPACE*

That a religious representation of science is apparent in some non-fiction science television programmes has been established. What the identification of this religious representation stimulates is exploration of the possibility of its serving a religious function. The potential for the emergence of a religion with its focal point the media representations of science detailed in the previous chapter requires analysis. As the above quote from Carl Sagan suggests the emergence of a religion of this kind has been anticipated, and welcomed, in the past. Mass media, as a central cultural institution in a modern western democracy, is potentially uniquely placed to impact the emergence of such a religion. The extent to which mass media could hamper or instead facilitate the emergence of a sanctified science is the central concern of this chapter.

I will base analysis of these issues in a Durkheimian conception of religion. The function of religious representations for Durkheim is to unite a group or community – to strengthen the solidarity between individuals. Individuals within groups are bound by a set of shared sentiments which, by their expression through symbolic means, are reinforced and made long-lasting.

Particular symbols at particular times are adopted by a group and imbued with sanctity. Television programmes are designed to serve the needs of a particular audience. They are widely watched with audiences in the hundreds of thousands. These viewers experience the representation of the programme at the same time. As such the religious representation of science in a television programme meets many of the requirements to serve as such a collective representation.

The specific nature of modern television viewership however, must be taken into account when considering the religious function of television programme. Developments such as On-demand TV have the potential to disrupt in important way the conditions of co-temporary viewership. However, similar contemporary developments in the shape of Social TV – the confluence of social media and television viewing – allow for the development and maintenance of communities around television representations. The effects of these new modes of audiencing must be taken into account when assessing the potential for the religious representation of science to serve a religious function.

In this chapter, I will therefore consider;

a) The processes which foster religious sentiment within a society
b) How a society directs and manages the religious sentiments that are produced via communal living
c) The possibility of the kinds of processes required to foster religious sentiment occurring in modern British society through media channels
d) How television is consumed in modern British society which may help or hinder the fostering of religious sentiment in a society or sub-group thereof.
e) If the religious portrayal of science, and how it is audienced, could plausibly serve a religious function

Religious Functioning in Modern Societies

For Durkheim, religious feeling is an inevitable outcome of communal living (1912). What is usually described as religion and ascribed to supernatural forces are for Durkheim the product of the force of social bonds. Religion provides a set of norms which guide the thoughts and actions of individuals in society. Religious (ritual) activity allows for the collective expression of these shared values, uniting individuals, most importantly through collective effervescence.

In traditional societies, collective effervescence occurs when individuals come together in close physical proximity and perform shared ritual activity. These activities are occasions apart from the normal everyday life of the individuals within the society. The everyday activity is mundane and thus profane; the ritual activity interrupts the mundane of everyday living and leads to its designation as sacred. This is the fundamental aspect of religious thought, the separation of the world into two distinct and mutually exclusive realms, the sacred and profane. The profane is the everyday. The sacred is that set apart from the everyday and around which prohibitions are constructed (Durkheim 1912). It is towards the sacred that ritual activity is directed.

During ritual gatherings, individuals feel a heightened sense of connection to other members of the group and transcendent connection to the 'other'. A heightened emotional state is generated through these collective ritual activities and is the hallmark of the collective effervescence. This heightened emotional state can lead individuals to have transcendental experiences during collective effervescence. Subsequently these experiences are ascribed a supernatural cause by the individuals involved in the collective effervescence. For Durkheim this transcendental experience is actually the product of the collective group activity.

Berger and Luckmann suggest that solidarities once produced serve the purpose of nomisation. Group membership orders the world of the individual and makes it meaningful (Berger and Luckmann 1991; Berger 2011). Explanations for phenomena in the world are provided by the shared understandings present in the group. A loss of solidarity leads to anomie – the world ceases to make sense to the individual. A function of religious activity which produces solidarity is thus shielding members of groups from a sense of meaninglessness. Religion is a sacred canopy that accounts for seemingly inexplicable phenomena in a way which makes sense to the group member.

> "Durkheim argued that our experiences of being connected as members of a social world are at the root of our most important categorisations of that world; they are at the root in particular of the sacred/profane distinction, which Durkheim argues underlies all religion in the usual sense of the term." (Couldry 2005, p. 4)

Modern societies are pluralised (Bruce 1995); they are large, dispersed and are made up of differentiated individuals, with less clearly expressed, uniform and strongly held beliefs and sentiments. Within these societies, human interaction, and ritual behaviour, is mediated through mass communication channels such as television. As a result, in modern western societies the opportunities for and characteristics of collective effervescences are altered. Mediated interaction may limit the circumstances by which collective effervescences (and through collective effervescence the periodical reinforcement of social bonds and nomisation) can occur.

However, for Durkheim, some form of religious sentiment is an inevitable by-product of social living. For the religious feeling which binds individuals into a group, and thus the group to persist, collective effervescences must occur. Therefore the avenues through which a society's inevitable religious feeling is channelled and expressed must be located. How, and in what ways, modern, pluralised societies collectively effervesce must be identified.

Media and Collective Effervescence

Cottle (2006) argues that physical proximity is not necessary for collective effervescences to occur. He argues that the same effects can be produced through mass communication media. He describes 'Mediatized rituals'[35] that act in the same way as traditional collective effervescences to reinforce social bonds and shared values and promote religious sentiment within a society. Cottle defines mediatised rituals as follows:

> "Mediatized rituals are those exceptional and performative media phenomena that serve to sustain and/or mobilize collective sentiments and solidarities on the basis of symbolization and a subjunctive orientation to what should or ought to be." (Cottle 2006 p. 415)

In Cottle's definition, the performative aspect of mediatised rituals is important. Rather than merely representing some ritual activity taking place in the world, the media are active in imbuing particular activities with ritual form and symbolism. It is through this treatment that certain things represented within the media are ascribed with ritual characteristics around which groups can coalesce and through which social bonds are reinforced.

> "This more performative understanding of media intervention, of 'media doing', helps to focus in on the media's promotion of some events, and not others, as exceptional, and how the media inscribe these with ritual meaning through the panoply of ritual forms, symbols, performances and claims upon imagined and actual collective identities." (Cottle 2008, p. 138)

Cottle has a broad six point scheme of media phenomena which he suggests qualify as mediatised rituals. These include Moral Panics, Celebratory Media Events (Olympic Games, Coronations), Conflicted Media Events (e.g. The OJ Simpson Trial), Media Disasters (e.g. Hurricane Katrina, 9/11), Media

[35] This is a contested concept. Couldry (2005) and Couldry and Rothenbueler (2007) argue that 'mediatised rituals' as a concept is better described in other theorising around media and rituals. The concept is useful in my analysis as it captures both the importance the media plays in actively imbuing certain media content with ritual form and symbolism, and in its recognition of the possibility of solidarity re-enforcing media content in a pluralised society.

Scandals and Mediatised Public Crises. These events are in some way 'out-of-the-ordinary', they disrupt the normal news cycle or media schedule.

> "By definition, the types of media events that can be described as 'mediatized rituals' are 'exceptional'; that is, they are salient or obtrude in terms of high-level media exposure and collective media performativity across different media outlets in space and time." (Cottle 2006, p. 416)

For Cottle, as Durkheim, rituals are abnormal, extraordinary. For Cottle, rituals remove those witnessing and involved in the ritual activity from their day-to-day lives. This state of affairs is not permanent however, and as such the temporal nature of mediatised rituals needs to be considered. These rituals are marked off in time, they have a start and end point. With certain mediatised rituals this temporal distinction is easier to identify (e.g. Olympic Games opening and closing ceremony). This temporality is important, as although physical proximity does not generally occur during a mediatised ritual, temporal co-occurrence often does. The sense of a shared audience in time - events experienced contemporaneously - can militate against the lack of a physical proximity (Cottle 2006).

The collectivities mobilised and solidarities reinforced by the mediatised rituals described above are national in scale. Pluralised societies, such as contemporary British society, contain sub-groups who organise around a smaller, more discrete set of beliefs and values (Bruce 1995). For Cottle, Mediatised Ritual activity can still serve these sub-groups, reinforcing these distinct solidarities;

> "The organizing force of rituals need not always be consensual nor uniformly inflected (Chaney, 1986; cf. Shils and Young, 1956), much less coextensive with a singular collectivity resident within national borders" (Cottle 2006, p. 415)

Solidarities in Pluralised Society

In a pluralised society, there are a large number of groups which individuals adhere to, claim affiliation with and from which they gain some sense of identity (Collins 2011). Within this type of society, these different groups will attach greater significance to particular things (including media products) than others. Larger and more widely dispersed groups may be affected by and coalesce around larger media events (e.g. the Olympics). Smaller groups will have their own focus of interest, shared values and representations around which they come together. These smaller groups will be subsumed by larger groups so individuals within the smaller groups will also have affiliation to the larger groups. However, the individuals in smaller groups will coalesce around particular things which other individuals in the larger group (or different smaller groups) will not.

When first broadcast, *Wonders* attracted a co-temporal audience of over two million people per episode. These two-million and more people coalesced around this media product. These programmes were designed in no small part to transport the viewer away from their day-to-day existence;

> Executive Producer H: "Sunday evening is a different thing from a weekday slot, escapism is the big word on a Sunday evening, you know its Monday morning, you just want to be somewhere else entirely,"

This removal from the everyday, the transportation to somewhere else entirely, is an important aspect of collective effervescence. Television is a mass-media, though audiences are physically dispersed, television viewing is a collective activity. Audiences view the same things at the same time. A programme designed to transport the viewer away from daily life, viewed co-temporally with millions of others lays the foundation for potential collective effervescence, the result of which is the production and maintenance of solidarity within this audience group.

However, in recent years the way in which television is consumed has changed. The advent of time-shifted viewing and the introduction of second and third screens into the living room have the potential to simultaneously fracture and unite audiences, with the attendant potential to or dissolve or reinforce solidarities.

Watching Television: Form & Function

Television as conceptualised in the above has a number of defining characteristics. It is a one-to-many medium. Feedback from the audience to the broadcaster occurs post-broadcast through audience ratings and measures of audience appreciation. What is broadcast is received contemporaneously by a physically dispersed audience, it is centrally scheduled and linear. There is very little real-time interaction between audience and broadcaster/film-maker and (apart from individuals sharing the same viewing space, generally small in number) no direct interaction between different members of the audience. Though physically separated, an audience for a programme are connected to one another through the knowledge that they are witnessing the same programme at the same time.

The above describes the model of television viewing prevalent for most of the 20th century and the early years of the 21st. In the previous decade, however, the way in which many audiences consume television programmes has changed markedly. Television sets no longer necessarily command the same power to unify their audiences, both temporally and in terms of the attention that is dedicated to them within the living room. The rise of time-shifted viewing, and the arrival of second and third screens in the form of tablet computers and mobile phones into the physical and mental space once occupied by television means that the potential for audiences to be divided, both in terms of attention and collective viewership, is higher. Television's ability to inspire collectiveness and collectively inspire is potentially reduced.

On-demand TV, Second-Screens and Social TV: Reshaping the Audience

On-demand TV, or time-shifted viewing (McCreery and Krugman 2015) has the potential to fracture audiences. Older linear forms of television produced a particular audience at a particular time. With the rise of on-demand television, audiences are less predictable and reliable than with previous linear forms (Lotz 2014). Audiences are no longer temporally coherent and this has the potential to reduce the sense of collective viewership.

Some critics (e.g. McCreery and Krugman 2015) have suggested that second screens can detract from the attention paid to television programmes by audiences. The divided attention of the audience lessens the impact of television programmes, weakening audience's connections to the programmes watched and, more importantly, to fellow audience members.

Both on-demand TV and second-screens can fracture an audience, detracting from television's solidarity maintaining ability. However, Moe et al. (2016) for instance, have argued that the introduction of these new technologies into the living room has had limited effect on television's ability to reproduce solidarity. In fact, these new modes of viewing may open up avenues through which solidarities can be further enhanced. One such development is Social Television.

Social Television

Social Television describes the convergence of television and social media. It is an area of increasing interest in industry and academic circles (as evidenced by for instance the Special Issue of Television and New Media titled *Rearticulating Audience Engagement: Social Media and Television* (eds. Moe et. al 2016). This area of study has detailed the kinds of ways the interaction between social media and television has (to a greater or lesser extent) impacted audiences' viewing habits. For instance, Wilson (2016) critiques the simplistic model of second-screen impact on TV audiencing described above.

She suggests that traditional conceptualisations of television audiencing fail to take into account television audiences actual viewing practises. For Wilson, television audiences' attention has always been differentiated, fractured. She claims;

> "There is no single mode of attention that can be attributed to the audience or to essential qualities inherent in the medium itself" (Wilson 2016, p. 182)

As such, she suggests that second-screens have the potential to both detract from and enhance audience engagement with television products. What effect a second-screen has is dependent upon a number of factors, most notably in Wilson's study, the genre of programme being viewed (Wilson 2016). What she and others (e.g. Selva 2016) suggest is that the second screen, through social media and other internet based services, allows viewers the opportunity to connect with other audience members beyond their immediate physical location. For broadcasters, the purpose of this is to capture and hold audience attention, to increase engagement between the audience and the broadcaster (and their products). For audiences, this allows for a tangible experience of connectedness with other audience members:

> "Viewed in this way, the second screen, particularly when connected to social media is holding oppositional forces of connection and dispersal in tension and offering the means through which audiences (re)connect" (Wilson 2016, p. 176)

What is interesting in the way that social TV is described by a number of its vocal proponents is the way in which it can be geared towards engaging an already extant community who have self-organised around particular television programmes. Wilson offers quotes from a number of industry figures who suggest things like;

> "By keeping their smartphones, tablets and laptops handy, viewers can get new insights into their shows and tap into an

> *active community* from the comfort of their couches" (Washenko 2014 cit. in Wilson 2016, p. 181)

In earlier discussion she suggests that programme specific apps or websites would be most appealing to individuals already invested in a programme and its attendant fan community;

> "It is likely that initiatives such as the Sherlock companion app will be taken up by an already existing fan community" (Wilson 2016, p. 180)

Viewed in this way, second screen technology can provide a conduit for members of already extant communities who have coalesced around a particular symbol or representation to interact or engage with one another in direct and immediate ways. What this also shows is that there is a perception amongst broadcasters that these communities exist and wish to be engaged in this way and be provided with the ability for members of these groups to engage with each other.

Social TV then appears at least to provide an avenue through which solidarities can be maintained amongst already existing groups, whilst providing the potential for further solidarities to be made (e.g. through the creation of specific twitter hashtags or other online communities). In contrast with this, on-demand TV appears to have the potential to dissolve these solidarities through inhibiting the circumstances within which collective effervescences come about.

On-Demand TV

Though the potential for audiences to be temporally dispersed has increased with the advent of on-demand TV, the extent to which this occurs is dependent on a number of factors. Broadcasters retain control of a schedule and are still firmly of the belief that when and where within the schedule a programme is placed will define to a great extent the overall size of its audience. Broadcasters only very recently have begun to aggregate on-demand, time shifted viewing figures into their measurements of a programme success. The 'overnights' (the collated figures which indicate the size of the audience on first broadcast) are still of primary importance to the broadcaster and film-makers, indicating a perception (possibly outdated) that overwhelmingly a programme's first-airing will draw the largest share of its audience (subsequent on-demand viewings only supplementing this).

> Executive Producer Q: "They've just started circulating as a regular daily digest the 'plus sevens', i.e. all the [viewing] figures in that last week, they consolidate them, so that's the 'plus sevens', it doesn't include iPlayer but it does include catch up, so no, it is acknowledged that it's absurd to continue with the overnights, but it is still the quickest, easiest, accessible metric and it is the dominant one"

However, even with this possible reduction in audience size for first airings the expected audience for a science documentary (a relatively niche genre) is still anywhere (depending on channel, time-slot, topic etc.) between 500,000 and 2 million viewers. *Wonders* drew an average of between 2.2 and 2.5million viewers across the first airing of the 4 episodes (BARB 2013). These are not insignificant numbers of viewers collectively sharing an experience contemporarily. As such television very much retains an ability to unite in time a significant subset of a national audience around a specific representation of science.

The Audience Reshaped

For Wilson the new TV landscape presents a fundamental contradiction. On the one hand the possibility and probability for audiences to be bought closer together, both to TV producers and to each other through engagement with social media, has markedly increased. On the other hand, time-shifted viewing and on-demand services have the potential to reduce first airing audience numbers by rendering the once entirely temporally homogenous TV audience into a dispersed and discontinuous group of potentially atomised individual viewers. As Wilson puts it;

> "The resultant challenge to the one-to-many model of broadcasting undermines the idea of TV as a shared cultural form while second screen innovations extol digital technology's promise to revolutionise TV viewing by connecting viewers across space via applications (apps) and social media sites" (Wilson 2016, p. 175)

However, despite the potentially dis-integrating impact of on-demand television, first scheduled broadcasts of science programmes (to reiterate, a comparatively niche genre) still attract audiences in the hundreds of thousands. The new television landscape also allows for greater connectedness between both programme makers and their audiences and tangible real-time connection between physically dispersed audience members. The potential for programme makers to know their audience and connect with members of it directly, and for members to connect with each other, is increased.

As I have previously suggested, television programmes are always made with an audience in mind, with the purpose of appealing to an (imagined) audience. Audience responses to programmes (as recorded by Nielsen ratings and Audience Appreciation Index measures) are the primary arbiter of the success of a programme and play a major part in the shaping of future programmes. Social TV may allow for a more immediate understanding of an audiences reaction to a TV programme, and for a fuller dialogue to be continued after broadcast, through which broadcasters and programme makers can hope to achieve a fuller, more detailed understanding of the audience who they are catering for. More importantly, the potential for these audiences to know and connect with each other is also increased.

Television provides audiences with shared experiences. Some of these experiences (for some viewers) are exceptional and transport the viewer away from their ordinary day-to-day experience. Audiences can now experience in tangible ways (through social media interaction) a sense of connection to other audience members. Though on-demand TV may have reduced the size of the contemporary (co-temporal) audience for a first broadcast of a programme, these audiences are still significant in size and through social media can connect with each other in real-time. This connection can (re)produce a set of shared understandings and values, provided by the programmes representation, that help the group member to make sense of the world (nomisation).

From a Durkheimian perspective, these are some of the vital prerequisites for the production of religious sentiment within a community. Shared, transcendent experience which produces solidarity amongst group members and allows them to make sense of the world captures a good part of what Durkheim means when he describes religion. What is relevant now is to investigate the extent to which the programmes which portray science in a religious way produce, or cater to, a collective who have a shared understanding which allows them to make sense of the world and who experience a sense of connection to each other through these programmes.

The Religious Portrayal of Science and its Audience

In 2011, Kim Shillinglaw, the then commissioning editor for science and natural history and now Controller of BBC 2, gave the following quote to the Observer magazine;

> "One of the things we get back from audience research, particularly with the big pieces we do in natural history, is that viewers feel very small and unimportant. In lots of ways you'd think that would be a negative response. You wouldn't put it top of your list of how you'd want to feel today. But clearly it is an emotionally rewarding experience. Something about being placed in a bigger context is very powerful for the audience." (Anthony 2011)

The idea that an audience responds well to grand, emotionally stimulating styles of presentation, which make them feel part of something bigger was reinforced in my interviews. For instance one senior executive suggested:

> Senior Executive K: "there's kind of two things that science programming does which is tells you about the world and tells you about science, but the other thing which we kind of cornered the market in is what I call wonder-science, which not only tells you the truth and the facts and the hard-core factual stuff of science and its history and all the rest of it, but makes you go 'wow' as well, and people really respond to that and they really enjoy that, so Brian Cox is one iteration of that…and you know as I say there is science fact in there, but there's a really strong emotional thing at the heart of it, which is this you just go wow"
>
> WMW: "so then there is, like you said, and maybe it's slightly flippant, but there is a kind of real sort of drive to provide that kind of, for the science to take up and provide that awe and spectacle –"
>
> Senior Executive K: "yeah I think so –"
>
> WMW: "– that thing that religious programming might have done before?"
>
> Senior Executive K: "yeah, in a, well and I don't think that is, and I think it's very important, our religious programming is very important, I'm not saying it's a replacement for it, but I think what I am saying is that it's a peculiar genre, in a way perhaps that history isn't in quite the same way, that it can provide a really strong emotional response as well as providing fact"

These quotes suggest that an audience responds to a presentation of science which transports individual viewers away from their everyday lives. This kind of representation of science stimulates an emotional response of awe. The religious portrayal can achieve this as it presents science as extraordinary. This portrayal could provide the representation around which audiences could collectively effervesce. This collective effervescence produces a sense of connection to others and through this a way of ordering the world.

Evidence for the solidarity producing and maintaining intent of some science programmes can be seen in the following quote. For one executive producer, a very clear part of his remit was serving a community , which he described as 'atheists like himself' who were not interested in the stories traditional religion had to tell, and instead wanted the "better" story science offered about the fundamental nature of the universe. He was happy to describe some of his films as "creation tales for atheists";

> Executive Producer P: "The other thing I say is that I like to think of the shows we do quite often as sort of creation tales for atheists, so I'm an atheist and I think a lot of people are these days, and we have our own narrative, we have a creation narrative, a really amazing one from the big bang, all the physics, and into genetics, and biology and evolution and genetics, so all the stuff in Genesis, we have a story, but a better story actually to tell from the moment the universe began to now, so I like to think a lot of the films we make fill, I'm going to sound really pompous, but so what, but we kind of give, they're sort of creation tales for atheists, narratives of how we got here, people are very interested in that, why are we here? What created us? And we don't have the option of going "ooh a big dude in the sky with white hair", we have to look at the evidence and go well this is what we observe in the universe around us and let's try and work backwards from that to figure out how we got here, for real, based on evidence, not fantasy, and many of the films that I've done are about those stories, the big bang or what happened shortly after the big bang, the formation of the first galaxies, how do stars form? How do elements get made in stars? All that kind of stuff, how did living things originate? How do we go from being single-cell bacteria to multi-cellular complex organisms? All these things are actually things I've made, one way or the other, have been in my films, and I never really thought about it, but when I look back I think well actually, a lot of the stuff we do in the kind of blue chip science is, in a very, very broad sense looking at the question of how did we get here, and trying to answer it, without recourse to fantasy"
>
> WMW: "but these programmes can actually provide that very function, of giving a narrative, presenting these stories in exactly those terms, here are these creation stories based on science?"

> Executive Producer P: "yeah, so it's creation stories, but creation stories – and this is the crucial thing, and don't, if you're going to say this make sure you say – creation stories based on evidence! And rational thought, not made up by some dude, you know"

For this respondent, his film making was not religious. Though he was telling these stories about the fundamental nature of the universe, what set his stories apart from the religious narratives was the evidence base, and the method by which the content for these stories had been gathered. To answer these fundamental questions, the modern atheist does not have recourse to "the big dude in the sky with the white beard"; he must look at the evidence, and through deduction and rational thought work back to first principles in explaining the world.

The problem is (as 40 plus years of STS has shown) that this understanding of science is mythical in the same way that the story of Moses receiving the 10 commandments on Mount Sinai and single-handedly writing the Pentateuch is mythical. Critical insight into the knowledge construction practices of science have shown it to be far from a purely rational enterprise of empirical testing and deduction, in the same way that critical exegesis of biblical literature showed it to be the product of a long socio-cultural and historical process of many writings and revisions.

From the Durkheimian perspective, his programmes were clearly intended to provide a community with a collective representation of science around which they could come together. Science presented as such can provide the material around which groups can collectively effervesce. In that way these programmes can provide the material for the production and maintenance of solidarity and the resulting shield from meaninglessness (nomisation).

We can see some indication of the religious portrayal fulfilling the function of nomisation. For instance, the following quote is taken from an online forum and discusses the impact of Brain Cox's Wonders of the Universe on one audience member

> "Stardust was a fascinating documentary - and very pagan considering it was about hard science. It started with Brian Cox attending a Hindu cremation on the banks of the Ganges and explaining that everything that dies is reborn. Every element that makes up our bodies has in the past been part of other bodies - people, animals, plants and the very rocks that make up our planet. After we die those elements will return to the earth to become new plants, animals and human beings. Of course, he was talking about this in a physical sense - although he was also touching on questions of metaphysics such as what are we and where do we come from? I found that this helped me come to terms with the death of my mother last week." (Badwitch 2011)

The particular style of presentation has impacted this audience member. They have accepted the idea of interconnectedness between all things which the religious portrayal of science emphasises. The idea that the elements 'return to the earth to become new plants' etc. echoes ideas of reincarnation. Most significantly, the final sentence shows that this style of presentation has acted as a theodicy, legitimating and explaining the anomic phenomena of experiencing the death of a loved one. For this audience member at least, a sense of order and meaning has been restored through the religious presentation of science.

Conclusions

Religious sentiment is the product of communal living and is reinforced and maintained through collective effervescences. Collective effervescences produce solidarity between group members. Though originally theorised as requiring the co-presence of individuals to take place, collective effervescences can occur in mediated societies where individuals are spatially separated. The potential for media representations to act as a collective representation around which groups in a society come together and collectively effervesce has potentially been enhanced with recent developments in media consumption, particularly the advent of Social TV. Collective effervescences do not need to occur on a national scale to have the effect of enhancing solidarity and providing nomisation. Sub-groups in pluralised societies can collectively effervesce on a smaller scale, coming together around representations specific to that sub-group, feeling a sense of connection to one another and through this being provided with meaning and a sense of world-ordering.

Some non-fiction science film-makers believe that a certain sub-group of the science television audience desires the kinds of programme that make them feel part of something bigger and that connect them to others. As has been shown in chapter five, film makers' primary motivation when making content is to satisfy their audience's perceived desires. Similarly, communicating science to a wide audience is seen as a good thing by filmmakers. The constraints of long-form science television mean that scientific knowledge must be corralled into a narrative form which does not faithfully represent the procedure by which the knowledge was created. These narratives are designed to satisfy the desires of an audience for good storytelling, and in some instances, for a story that makes audience members feel part of something bigger. These kinds of representations, in concert with modern viewing habits such as social TV, provide the potential opportunity for this audience subset to collectively effervesce.

The extent to which a sub-group of British society is actively involved in coming together around this representation and using it as a basis for solidarity is not explored here. However, there is evidence that some film-makers see their programmes as designed to form the basis for just this kind of solidarity. There is also indicative evidence that these programmes have the effect of nomisation, providing some audience members at least with an account of science through which they are able to impute order onto the world and justify seemingly meaningless phenomena.

There are, however, problems with the religious representation of science having a religious function. The religious representation of science is an inaccurate representation of science. The consequence of collective groupings coming together around this representation of science is that science is misunderstood. As has been made clear in the introduction to this thesis and in chapter two, concerns over public misunderstanding of science are not new. However, the particular character of this misunderstanding, of attributing to science the status of a religion, has, from the normative perspective I adopt in the thesis, some particularly problematic consequences.

Establishing a religion, in the Durkheimian sense, around the religious representation of science means establishing a religion around a very particular image of science. This image of science, however, elides aspects of science – the formative aspirations which characterise it as a form of life – that would be beneficial to democracy if collectively understood. A religion based around the aspects of science foregrounded in the religious representation of science would ignore science's aspirations to such things as doubt, scepticism and the maintenance of the essential tension between individual and community. It is these aspirations of science that are beneficial for individuals in a modern democracy to understand and apply in their own day-to-day lives.

If individuals do not understand science in these terms, as characterised by formative aspirations which align with democratic values and if followed facilitate the freedoms of a citizen in a democracy, they lose a vital cultural resource. Without this understanding, the ability for citizens to properly scrutinise and hold to account the institutions of their society is curtailed. Indeed, it is the understanding science as just this kind of cultural resource which a modern citizen must possess if they are to resist the emergence of a totalitarian religion based in the religious representation of science.

CHAPTER 8
THE *SOCIETY OF SACRED SCIENCE* AND HOW IT IS TO BE AVOIDED

In the *Society of Sacred Science* a religious understanding of science is omnipresent. Through mapping the contours of such an imagined society, I will show how a society-wide sanctification of science has negative consequences both for the individuals inhabiting the society, and eventually for the practice of science within the society itself. The *Society of Sacred Science* is designed to serve as a warning. It charts one potential extreme consequence of persisting with mass media representations that present science as perfect, certain and all-encompassing. My thought experiment is presented in such a way so as to cast the recommendations I make in that much more serious a light. The recommendations I make for avoiding the production of religious representations of science would help our own society avoid the worst excesses of the *Society of Sacred Science*, and thus these suggestions should be heeded.

The narrative and aesthetic devices used in some long-form documentaries facilitate a religious portrayal. These documentaries use closed-ended narrative structures which present science as definitive. Documentary formats which use other, more open-ended narrative structures would be preferable when representing science. Other formats which better reveal the more prosaic, day-to-day activities of science could be used. Fly-on-the-wall documentary may reveal the more human elements of scientific practice, making it harder to represent science as a reified, asocial endeavour.

The canonical model attributes a status to science which renders it difficult to critique. Utilising different televisual forms to engage an audience would render the canonical model of science currently adopted within the community of film-makers less useful. A different, non-canonical model of science may allow for an increase in 'journalistic scrutiny' of science amongst film-makers, making it more difficult for uncritical representations of science to be produced. The inclusion within the film-making process of individuals with more active experience of practising science, who are reflexive in their understanding of how science works and willing to communicate this process would help to produce more nuanced, contextual representations of science. Including social scientists who have a contextual understanding of science would also help in the production of these representations.

In the final section of the chapter, I will describe science according to Elective Modernism (EM). Elective Modernism suggests that science is a form of life differentiated from others by the formative aspirations of the scientific community. An Elective Modernist portrayal of science if produced would emphasise the values which the scientific community aspire to uphold. Science would be presented as an exemplary institution in a modern society which could provide normative guidance for democratic citizens, as it aspirations would be shown to align with many of the aspirations of a democracy.

The *Society of Sacred Science*

Durkheim argues that societies must produce religious feeling as a necessary by-product of their existence. Collective living inspires experiences of the transcendental - this is then redirected onto signs and symbols. These signs and symbols are imbued with sacred energy but then over time, through contact with the profane, become profane themselves. This profanation occurs through the sacred coming into contact with the profane human world. The profane world is impermanent, polluted, subject to change and human fallibility. If the social provenance of sacred things is recognised, they become de-sanctified. Societies, however must produce sacred energy, and direct it toward some collection of signs or symbols. Thus new ideas or ideas can be instituted in place of the old and become sacred (Durkheim 1912).

Which ideas, signs and symbols sacred energy is directed towards, according to Weber (Parsons 1944), will be influenced by the particular social organisation of the society. Hierarchical social organisations may impute a similar cosmic order. If science is an important aspect of the culture, is given respect and attention, whose practitioners are generally trusted and respected, the sanctification of science may be more likely. In chapters 6 and 7 I have argued that through the representations of science in some television programmes and the potential ways in which these programmes are audienced, this process can be identified. Science is presented using the language and iconography of religion, and these representations function to connect individuals and provide a sense of order and meaning in the world.

It may seem that this is an unproblematic state of affairs. Though the solidarity produced is based around an inaccurate representation of science, the fact that meaning and connection is being provided could be viewed as a positive (Durkheim 1912). Those individuals who are shielded from meaningless by this conception of science would value science for this very reason, and be content with their understanding. In a pluralised society, it is possible for groups to coalesce around a variety of representations with little or no consequence to other members of the society

However, sanctifying science has some potentially damaging consequences, which I will now attempt to outline with the use of a brief thought experiment. I will describe some of the essential characteristics of a society in which science is sanctified. I will name this imagined society the *Society of Sacred Science*. In describing this society I will trace its development along Durkheimian lines and hope to point out the fundamental flaws in its organisation. I will show how this society threatens the freedoms of the individuals who inhabit it and the very practice of science itself.

Sacred Science

In the *Society of Sacred Science*, scientific knowledge would be definitive and immutable. Science would be all-encompassing, able to explain everything about the world. A comprehensive creation narrative would be provided by science, justifying human existence and placing humanity at the pinnacle of creation. Humanity's place there would be justified by its possession of scientific understandings of the world.

This conception of science would be part of the taken-for-granted reality of the members of the *Society of Sacred Science*. In the same way that for the medieval man the King's right to rule was divine, or for the ancient Egyptian the Pharaoh was the earthly instantiation of the gods, so too would science's immutability, certainty and explanatory omni-competence be accepted as a given. Accepting this set of beliefs would form part of the natural attitude in this society (Schutz and Luckmann 1973).

This understanding of science would engender solidarity between individuals. The shared conception of the world, total in its understanding, would provide a shield from meaninglessness – all phenomena could be explained or justified in reference to sacred scientific understandings. A sense of connection to others would be felt through this shared belief. The symbols of science would be the 'collective representations' around which individuals coalesce.

A fundamentally erroneous understanding of science would be widespread. A number of important characteristics of science would be misunderstood. Science would not appear as the product of skilled, yet negotiated human practise which is subject to change and revision. Through convening with nature scientists would bring forth knowledge unerringly. Rather than being open-ended and subject to change, science would be fundamentally correct in its present understanding of the world. Science would provide certainty and totality of explanation, justifying our existence and consoling us in the face of the seemingly inexplicable.

What would be some of the identifiable differences from our own society in the *Society of Sacred Science*? Though this is not knowable *a priori*, it seems highly likely that this understanding would have implications for the interaction between publics, policy and science. How scientists were treated and how scientific based policy decisions were made would differ significantly.

Sacred Scientists

In the *Society of Sacred Science*, scientists would be members of a priesthood akin to the Catholic priesthood of medieval Europe. These kinds of priests have access to special knowledge which lay members lack, a knowledge which is vested with an unquestionable authority (Lynch and Adamo 2014). Priesthoods resist the intervention of non-initiated members. The involvement of wider, non-scientific participation in debates involving scientific issues which have direct impacts on public life would be rendered unnecessary. Science policy debates would happen behind closed doors, and the conclusions of these debates would be handed down *ex cathedra* to a quiescent public.

There are a number of outcomes which could be envisaged in this society. Some could even be seen as positive. A public entirely enthral to the proclamations of scientists would not take seriously climate change denial, the arguments of proponents of anti-vaccination or advocates for intelligent design. Many would argue that this would be preferable to the state of things in our own society.

However, within the society of sanctified science, the justification for rejecting these arguments is built on an erroneous conception of science. In certain instances of science-public interaction this may produce desirable outcomes. However, justifying the means by the end is philosophically problematic. There are also more fundamental moral and practical problems inherent in the *Society of Sacred Science* which far outweigh any perceivable benefits this social organisation may produce.

On a practical level, the establishment of a scientific priesthood would result in a drastic limiting of the range of expertise included in technical debates[36] . Only members of the scientific priesthood would be viewed as being able to legitimately contribute. Non-scientific expertise would be illegitimate. The outcomes of these debates would be justified because they were provided by scientists. In more general terms, the scientific priesthood would have free rein to plan and undertake any course of research it wanted to. Public oversight would be minimised, as it would be scientists who know best in the areas where science and public policy intersect. This society could be described as a "techno-theocracy"; a society governed by an elite knowledge class, who had access to and control over entirely infallible knowledge which was essentially othered from its human source of creation.

The Individual in the *Society of Sacred Science*

The individuals who inhabit the *Society of Sacred Science* feel a sense of solidarity, a connection to each other, as they share an understanding of the world based on the explanations provided by science. However, the particular character of this understanding of science has wider implications. It points to an underlying issue with how modern societies should be organised. Herbert Marcuse's One-Dimensional Man highlights some of the dangers of the social organisation of the *Society of Sacred Science*.

Marcuse recognises the genesis of one-dimensional society in the economic and technological developments of the 19th and 20th centuries. He suggests that the rise of global economic orders (capitalism, communism) and technological development have, over time, demanded a greater and greater submission of the individual will and reason to the demands of the

[36] These are debates where issues of science and technology intersect with the public and/or policy. By virtue of their expertise, scientists with relevant knowledge and experience are able to legitimately contribute to these debates. However, there may be non-scientists who also have legitimate expertise in regard to specific technical issues gained through other means (e.g. practical/lived experience). Collins et al. (2014) refer to these kinds of debates as "technological decision making in the public domain" (Collins et al. 2014, p. 186). Importantly, the requirement to qualify for legitimate inclusion in these debates is *relevant* expertise, whether scientific or non-scientific.

overarching and economic and technological systems. In his forward to the second edition of Marcuse (2002), Kellner summarises Marcuse's argument:

> "Critical reason was thus a creative principle which was the source of both the individual's liberation and society's advancement. The development of modern industry and technological rationality, however, undermined the basis of individual rationality. As capitalism and technology developed, advanced industrial society demanded increasing accommodation to the economic and social apparatus and submission to increasing domination and administration. Hence, a "mechanics of conformity" spread throughout the society. The efficiency and power of administration overwhelmed the individual, who gradually lost the earlier traits of critical rationality (i.e., autonomy, dissent, the power of negation), thus producing a "one-dimensional society" and "one-dimensional man."" (Marcuse 2002, p. xix)

One-dimensional societies are characterised by the inability of the individual effectively to resist the social order and, as a result, a lack of individual autonomy. Societies in which there are no legitimate alternate standpoints from which to critique current arrangements are one-dimensional. In 'multi-dimensional societies' these alternate standpoints can be provided by a range of cultural institutions. A multi-dimensional society holds in tension a variety of meaning making institutions, diverse vantage points from which other aspects of the society can be assessed. These are absent in one-dimensional society. One-dimensional man has meaning made for him by a totalising system, rather than the ability to create meaning for himself by drawing on the variegated patchwork of meaning making institutions present in a multi-dimensional society.

As a result, one-dimensional societies proscribe individual choice. Freedom in these societies is illusory, as the ultimate freedom for the individual to reject, or 'negate' any or all aspects of the social order is absent. This kind of negation of the individual will is identifiable in any overarching system that limits the individual's ability to critique the current social/political/power arrangements. Fiction is replete with examples of these kinds of societies. Zamyatin's *We*, Orwell's *1984* and Huxley's *Brave New World* all present the reader with a society in which resistance to the social order of things is impossible for the individual.

The *Society of Sacred Science* would be a one-dimensional society. In this society, science would 'colonise' other institutions. Other cultural or institutional forces which are present in democratic society and can act to provide solidarity or other means of cultural expression would be stymied. Science would be the totalising framework by which meaning was made

Understanding science as certain, definitive and all-encompassing reduces the ability of the individuals to hold science to account. Individuals are dissuaded from dissent and instead encouraged to accept unquestionably a version of science as certain, unchanging and all-encompassing in its scope. As a result, individuals' ability to operate freely, to resist the totalising conception of science, to negate the social order, are curtailed. This social organisation, the product of a solidarity engendered through the religious understanding of science, is non-emancipatory.

> "One-dimensional man…it is not able to resist domination, nor to act autonomously, for it identifies with public behaviour and imitates and submits to the powers that be. Lacking the power of authentic self-activity, one-dimensional man submits to increasingly total domination." (Marcuse 2002, p. xxviii)

The social organisation of the *Society of Sacred Science* disguises the actual characteristics of science as it is (and can only effectively be) practised, imputes an unwarranted epistemological status upon the knowledge the processes of science create and, as a result, creates a society in which the individual is subject to the constraints of a totalitarian regime. Ironically, the conception of science in the *Society of Sacred Science* disguises the very characteristics of science, an understanding of which, if widespread and properly valued, would aid the development of individual freedom and autonomy and scientific knowledge itself.

This thought experiment has attempted to underline the problems inherent to the sanctification of science. If science becomes sacred, individual freedom is undermined. I am not claiming that this is a process that is occurring wholesale in our society. However, I have shown in chapter six that a religious representation of science is identifiable in television programmes and in chapter seven that there is indicative evidence that this religious representation can serve a religious function; uniting individuals and providing them the framework for ordering their experiences of the world. These are important aspects of the sanctification of science. The above thought experiment has highlighted the dangers of the continuation of this process. The sanctification of science must be avoided.

Avoiding Sanctification and Producing 'Contextual' Representations of Science

The sanctification of science can be avoided and a more accurate and socially beneficial understanding of science enculturated. As the understanding of science amongst the general public is shaped to a large extent by the media products they are exposed to, these media products need to avoid representing science as a religion. Using techniques of engagement that do not rely on closed-ended narrative techniques would help to limit the religious portrayal of science in long-form science documentaries. Inculcating a more nuanced attitude towards science within the film-making community, through inclusion of scientists with a more reflexive attitude to science, and others who understand 'how science works', would help to limit the tendency of science films to do "science PR". This would help to produce representations of science which would be less likely to promote a religious understanding of science.

Introducing Novel Representational Forms into Science Film-Making

Elements of long-form documentary enable the religious portrayal of science. The kinds of narratives that are utilised in long form science documentaries to engage an audience present science as certain and unchanging. The requirement for narrative closure de-emphasises the open-endedness of science. The utilisation of beautiful imagery and emotionally stimulating music promotes awe in the face of science, underscoring the idea that science can provide meaning. These are important elements of the religious portrayal of science. These formats should therefore be avoided.

Other styles of film-making are less prone to portraying science in a religious way (as seen in *Bang! goes the Theory*) so these would seem preferable to those which are more conducive to a religious portrayal of science. However, television demands variety. If all science programmes looked the same the creative potential of science film-making would be curtailed. As importantly, the potential to reach diverse audiences with important information about science would be limited. Not all audiences respond to or are interested in magazine format programmes.

To combat this limiting of creativity, and attract a range of audiences other film-making styles which are not normally utilised in science film-making could be used. Science films could be made in the fly-on-the-wall documentary style, a style that is rarely utilised in programmes about science. Film-makers have resisted making science films in this style in the past, as they claim that the world of science is not inherently compelling enough to warrant an observational style film. This view of science can be attributed in part to the canonical model of science. Science viewed as fundamentally asocial and algorithmic, devoid of compelling social interaction appears singularly inappropriate for the observational genre. However, divested of its canonical trappings, science is rendered a fundamentally human endeavour, populated by individuals with ambitions and desires, experiencing successes and failures and involved in social activity familiar to many different social groups. Capturing this in the observational style would counteract some of the sanctifying tendencies of the traditional expository narratives utilised in science films. Representations of the day-to-day goings on in a lab as shown through the observational documentary would humanise science and its sanctification would be avoided.

Science film-making which eschews the usual documentary conventions of science television has been attempted by film-makers outside of the mainstream of network television. Sternberg (2010) has attempted a 'constructivist' alternative to the classic documentary film titled *Hopeful Monsters*. In his film he attempts to represent more faithfully the process of scientific knowledge creation, its difficulties and setbacks, the controversies and fundamental importance of the scientific community in the construction of scientific facts.

> "The narrative of *Hopeful Monsters* is both more meandering and less resolved, representing science as a process of trying things out, backtracking and digression—far from the focused clarity and directionality that the word 'method' connotes" (Sternberg 2010, p. 178)

The film follows the work and life of Donald Williamson, a scientist on the fringe of the community of marine biologists by virtue of his controversial views on the multiphasic life cycles of marine animals. We see Williamson in his day-to-day work on the Isle of Man. Sternberg is more of a presence in the film than is usually the case in science documentaries, and during the film steps out from behind the camera to aid Williamson in completing some of the simpler tasks required in his work[37]. The film bears witness to the various failures attendant in the everyday practise of science. For instance, the

[37] Sternberg carries out intricate or delicate tasks under the direction of Williamson who is unable to perform these tasks with his own hands due to illness/old-age.

audience is exposed to the failure of Williamson to encourage various sea creatures to spawn

> "*Hopeful Monster* is concerned to demonstrate the texture of the daily efforts that make up much of scientific research."(Sternberg 2010, p. 179)

Comparing the narrative form employed in his film with that of the narrative form commonly utilised in science documentaries, Sternberg writes:

> "The incomplete narrative of *Hopeful Monsters* reframes the question to ask not what is success but when is success. The film is concerned not to demonstrate the truth of Williamson's theory but to represent the process by which it is made true— a process that takes time." (Sternberg 2010, p. 179)

Sternberg has shown that it is possible to construct a sociological portrayal of science in film. The proliferation of this kind of portrayal in more mainstream media would help to disseminate a more accurate conception of science than is offered by the religious portrayal.

Undermining the 'Canonical Model of Science' in Film-Making

The necessity to produce engaging films, and some of the representative forms which film-makers currently use to do this, means that science film-makers adopt the canonical model of science. To enhance the engagement potential of a programme, film-makers utilise fictional narrative structures within expository documentaries which misrepresent the processes of science. Science facts are faithfully represented within these programmes, and science film-makers see this as faithfully representing science in general as by adopting the canonical model of science, they understand science to produce isolated facts.

If different techniques for engaging an audience are utilised, then adopting the canonical model of science will not be as useful to science film-makers. If science films attempt to engage an audience through showing the trials and tribulations of the scientific process, then faithful representation of this process, rather than representation of isolated science facts, will be required.

If these different techniques for engagement are adopted, this will allow for more of a nuanced, contextual model of science to come to the fore within the film-making process (both behind and in front of the camera). Some individuals currently making films have this kind of understanding, but due to the ways in which science film-makers currently attempt to engage their audience, this understanding is suppressed.

The following quote comes from a film maker, who reached the level of executive producer and independent commissioner, and who before his time in television had held a post-doctoral research position (this individual had the most first-hand experience of science of any of my interviewees who worked behind the camera):

> Executive Producer M: "I am concerned to tell people, there's a big question that I'm trying to tackle, it's a very hard one, it's not just what does science tell you, but how and why can we trust what science tells us, because science is imperfect, but there isn't a better way of working out how the world works, we haven't, we just haven't come up with it, so not only do you need to say this result says this but you also need to find a way of trying to convey the fact that this result has come from a lot of discussion, a lot of argument, a lot of debate and it isn't something plucked out of mid-air"

This interviewee expressed knowledge of some of the difficulties of doing science, and the social processes by which scientific knowledge is produced. He also stressed the fact that it was of vital importance for audiences to understand this process. The ability to represent these aspects of science faithfully is difficult given the way in which film-makes currently attempt to engage their audiences.

The production of a contextual representation of science is also complicated by how the purpose of science film-making is understood by both scientists who contribute to films and film-makers. It is not necessarily the case that individuals with more experience of science are more likely to communicate a nuanced, 'warts-and-all' version of science. As the "science wars" showed some scientists may reject outright the nuanced, contextual view of science offered by the sociology of science (Ross 1996; Labinger and Collins 2001). Other scientists may simply have no knowledge of the ability to possess this "reflective understanding" (Collins and Evans 2017). As scientists inhabiting the taken-for-granted reality of science, those moments which undermine this reality, the controversies where the social intrudes upon rational, algorithmic process, are rare. When this occurs, those social elements which closed the controversy, or established the new piece of knowledge, are eliminated post-hoc from the understanding of even those scientists involved in the process. Science once again appears as the operation of logical, algorithmic rules (Collins 1992).

The religious representation of science as certain, definitive, and asocial may be seen as broadly faithful by many scientists inhabiting the taken-for-granted reality of science. Those scientists who understand but reject the sociological understanding of science may feel that representations that do not contain the uncertainties and social processes are of benefit to public understanding. Scientists involved in media work see this work as public relations. The belief that current media representations of science increase public support for science suggests that the ways in which science is currently represented are broadly supported by scientists involved in media work.

Science film-makers help to facilitate this "science PR" work. Science film-makers see the primary purpose of their films as promoting science to the viewing public. Increasing positive public attitudes towards science is seen as a worthy and important undertaking by science film-makers. In adopting the canonical model of science, film-makers, as well as being influenced in regard to which aspects of science are represented, attribute a status to science which renders it resistant to critical scrutiny. Scientists are able to pursue public relations through their involvement in long-from science documentaries, and film-makers are happy to facilitate this. However, allowing this to occur can lead to the production of the religious portrayal of science.

To help to counteract this, certain types of scientist need to engage in media work; scientists who can compartmentalise. These scientists are reflexive of their own practice; they can pursue knowledge in science in a naively realist way, however, they are aware of and accept sociological understandings of science. When representing science to the public, they are able to provide contextual accounts of scientific work. These scientists can be described, from the perspective of elective modernism, as 'Owls', as they are able to look both ways[38] (Collins and Evans 2017).

Also required is more journalistic scrutiny of science in science film-making. The same kind of scrutiny that is applied to other social institutions should be applied to science. The inclusion of both sociologists of science, and more reflexive scientists would be beneficial to science film-making in this regard. These individuals are able to see beyond the glamour of the canonical model of science. They understand that science is a social institution, similar to any other. Though this may prove unpopular with some scientists, these individuals could aid in the production of science films which avoided the religious representation of science, and instead produced a representation which is more beneficial to public understanding.

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[38] The 'Owl' metaphor derives from a quote, widely attributed to Richard Feynman, regarding the relevance of philosophical studies of science to practising scientists; "The philosophy of science is as useful to scientists as ornithology is to birds". Collins and Evans (2017) construct a typology of scientists around this quotation. They describe most practising scientists as 'eagles'. They tend to 'look in one direction', being guided by the taken for granted assumptions of science and ignoring the contribution of social analysts of science. This allows them to pursue scientific knowledge 'objectively' in a naively realist fashion. Hawks are similar to eagles, but actively attempt to refute and undermine sociological analysis of science. Many Hawkes were involved in the science wars, and celebrity scientists such as Feynman or Richard Dawkins, display 'hawkish' tendencies. Owls, on the other hand, are scientists who embrace sociological analysis of science. They possess 'reflective understanding' of their own practises, allowing them to recognise the relevance of the sociologists findings. However, they are also able to compartmentalise. When undertaking scientific work, they are able to pursue it in a naively realist way. When representing science to the outside world, Owls can emphasise the inherent social constitution of science. It is for this reason that they would be most appropriate for communicating science to the public.

Elective Modernism

Elective modernism (EM) is the normative element to Collins and Evans' 'Third Wave of Science Studies Programme' (2002; 2007). EM positions science as more than just a resource, but as a central element of modern culture (Collins and Evans 2007). For EM, science is identifiable via the formative intentions of the scientific community. These formative intentions are both practically and morally good and should be influential in the moral organisation of a modern society. EM is elective as it offers a choice to value science based on its formative intentions and modern as it is the formative aspirations of science that are to be valued (Collins and Evans 2017). Under EM, representing science as being defined by the formative aspirations of the scientific community, and showing that these formative intentions are synonymous with many democratic values, would have beneficial effects for society as a whole. The formative aspirations of the scientific community have been outlined in detail in Chapter 1. They are re-articulated briefly in Table 15.

EM suggests that the formative intentions of the scientific community should form part of the corpus of values held in a modern society. Some of these values will have a broader application in a modern society than others. For instance, the commitment to universalism seems a more pressing and ubiquitous concern for a modern society than the commitment to clarity or the small legitimate locus of interpretation[39]. Furthermore, there is no appeal to the absolute or fundamental moral worth of the values espoused under Elective Modernism. These values are not suggested to be the ultimate expression of moral perfection. Nor is it suggested that the formative

[39] The small locus of legitimate interpretation of science (LLI) refers to the idea that a high degree of socialisation and immersion in an expert community is required before scientific knowledge can be legitimately interpreted. In this way the LLI is narrow or restricted; only those few with the required expertise (gained through socialisation by and immersion in a community) can offer legitimate interpretation of new scientific findings. In some areas of modern society, obscurity or a wide locus of legitimate interpretation is preferable. For instance, conceptual art can legitimately be interpreted by anyone and in any way they desire; this kind of art resists definitive categorisation and opens itself up to multiple interpretation in ways which scientific knowledge should not do.

aspirations of the scientific community can provide complete moral guidance for society. Other sources of guidance are required to deal with issues such as aesthetics, our relation to other species and existential questions concerning the fundamental value of human life. Rather the formative aspirations of science are suggested as being the kinds of principles a democratic society ought to include in its corpus of values if it is to promote the freedom, autonomy and prosperity of its citizens.

FORMATIVE ASPIRATIONS OF SCIENCE
Observation: finding things out through looking at the world
Corroboration: repeated looking means more evidence/support for theory
Falsification: claims should be open to being disproved – how this could occur should be set out
Organised Scepticism: claims must be open to criticism, and community must question new claims (doubt in spite of belief)
Open-endedness: science isn't finished or certain/definitive
Generality: the wider the application of a theory/idea the better
Locus of Legitimate Interpretation (small, centred): those best positioned to interpret scientific knowledge are closest to its production (other core-set scientists) – opposite to arts
Clarity: attempt to convey information so it is only interpretable in the way the conveyor intends
Universalism: science open to all regardless of gender, creed, sexuality. People judged on quality of their scientific practise
Disinterestedness: science done not in service of own gain or with overt political ends
Honesty and Integrity
Continuity: new knowledge produced should try and fit with that already conceived – revolution should be undertaken reluctantly
Expertise: valuing the contribution of people who know what they are doing and what they are talking about – not just people who are credentialed/in authority (though it is difficult to separate the two)
Essential Tension: individual can find things which go against mainstream understanding, and eventually overturn it

TABLE 15

Rawls' Original Position Argument

One way in which to justify the adoption of the formative intentions of the scientific community as morally worthwhile guiding principles is to utilise Rawls' Original Position argument (Rawls and Erin 2001). The Original Position argument is a thought experiment which attempts to posit the ideal conditions from which members of a society could negotiate a social contract. The Original Position supersedes the 'state of nature' found in the work of earlier political philosophers such as Hobbes (1996). This state of nature is considered to be an inappropriate position from which to negotiate a social contract as within it there will be inherent inequalities between the members – in terms of strength, intelligence or access to resources. Thus, in the state of nature, it could be possible for the strong to manipulate the weak to their own ends, undermining the legitimacy of any social contract negotiated. In the Original Position argument members of the nascent community are placed behind a veil of ignorance. They are unaware of their strengths, weaknesses and resources relative to the other members of their community. From this position, Rawls argues, they will negotiate a social contract which contains two principles of justice. The first of these guarantees the equal rights and freedoms of individuals. The second guarantees equality of access to those things (material, cultural, intellectual) that allow the individual to pursue their interests to the best of their ability.

From an original position the formative aspirations of science would be factored into a negotiated social contract. The aspirations of honesty and integrity, universalism, disinterestedness and the maintenance of the essential tension between individual and community are all values which make provision for individual liberty. The aspirations of empiricism and valuing expertise allows for the construction of a social framework within which individuals can prosper

> "A good society will be informed by, among other things, scientific values for these are democratic values." (Collins et al. 2010, p. 195)

A society which did not aspire to universalism in its treatment of its members would not fit with the two criteria of justice outlined in the original position argument. It would limit the possibilities of some members to reach their full potential to the detriment of these individuals and the society as a whole. A society that did not aspire to a degree of scepticism would exhibit totalitarian tendencies. Blindly accepting the proclamations of authority would undermine the accountability of those in power, with the attendant consequence being the inability for some individuals in the society to prosper. A society that did not value expertise would be subject to manipulation by hucksters and charlatans. The power to direct public opinion would rest with those with the loudest voice, the most appealing sales pitch, rather than the best informed. Once again, a society so organised would have limited ability to provide the necessary framework within which individuals could maximise their potential.

Understanding science as a form of life defined by the formative aspirations of the community of scientists means its important links to the project of democracy are visible. Failure to understand this can result in the failure to properly appreciate these values, with the potential for the kinds of results that I have outlined above in my description of the *Society of Sacred Science*. What is required therefore is a way of representing science so that its formative aspirations are foregrounded.

An Elective Modernist portrayal of Science

An elective modernist portrayal of science would resemble in many ways the portrayal found in Hopeful Monsters. Similar story structures would be utilised, which stress the open-endedness of science. Similar visuals, which reveal the day-to-day work of science would also be included. The elective modernist portrayal would also emphasise the values which the scientific community attempts to uphold in its day-to-day practice.

I have created the following statements as illustrative of the kind it would be desirable to hear from scientists in an Elective Modernist representation of science;

> "We can never be completely sure of a scientific fact, but we think the best way of finding things out about the world is through observing things and doing experiments and trying to

replicate the results of those experiments. It doesn't always work out as we hope or expect but we keep trying to do things in this way"

"I know that the lab X is working in is underfunded and their equipment isn't the best, but I still try and take their experimental results seriously if they've gone about them in the right way"

"If the work is up to standard then it doesn't matter if it was carried out by a woman, or an Englishman or anything else, at least that's how I try and approach new findings"

"Well Z's work was all in pursuit of prize money, and the fame that comes with it, so I find it much harder to trust his results. That just isn't the right reason for pursuing a line of research, and most people in the field, in science as a whole, would agree with me."

"Whenever you're presented with a finding that doesn't fit with accepted theory you are sceptical. Of course, you pay more attention if it's Professor Y at the Institute for X because you know he has the track record and the ability to find something like this, but you still have to try and scrutinise the results in the same way as if they had been presented to you by your post-doc."

In including these kinds of statements it would be hoped that the formative aspirations of the scientific community would be communicated to the audience. This portrayal would attempt to show that scientists aspire to behave in ways which other members of a democratic society would approve of. Audiences, it would be hoped, would take as exemplary the conduct of scientists. If this kind of portrayal of science was produced, then not only would a more accurate picture of science be presented for public consumption, but one which had the ability to influence public behaviour in positive ways would be on offer.

Conclusions

Avoiding the religious representation of science is an important part of curtailing any tendency for science to be sanctified within our society. As I have tried to show with my description of the *Society of Sacred Science*, the potential negative consequences of a sanctified science are severe, both for the individuals inhabiting the society and eventually for the practice of science itself.

Both the use of different film-making techniques and a shift in understanding amongst film-makers would help to reduce the chances of science being represented as a religion. As well as avoiding these religious representations, this contextual understanding and the deployment of new film-making techniques would help to produce more representations of science which reveal the social provenance of scientific knowledge. This kind of portrayal would share many similarities with an Elective Modernist portrayal of science. There would be similar focus on the process of science, but the EM portrayal would emphasise the formative intentions of the scientific community, and their relevance and importance to democracy.

Of course, film-makers would still have to satisfy the demands of their profession, not least making films which attract as big an audience as possible. It is still possible for these new formats to be utilised, and perhaps to attract audiences who are not attracted to the current style of science documentary film. Observational documentaries are often very popular. The Channel 4 obs-doc series *Educating Essex* received consistent viewing figures of between 1.5 and 2.5 million viewers, whilst the same broadcaster's *24 hours in A&E* received rating of upwards of 3 million (BARB 2013).

A problem that still requires a solution is the necessity for societies to direct their sanctifying energy onto particular collective representations. If societies require shared symbols around which collective effervescence can occur and which produce and maintain solidarity, where are these symbols to be found?

One answer could be provided by the elective modernist representation of science itself.

A solidarity constructed around a representation of science that held up its formative aspirations as science's defining and 'sacred' characteristics would alleviate the problems inherent to the society of sacred science outlined above. It would be a solidarity built around a more faithful representation of science as it is practised. It would inculcate in those communities that were bound by it a healthy sense of scepticism towards claims made from authority, allowing for the proper holding to account of science. Furthermore, this solidarity would be organised around a set of guiding principles which explicitly rejects the total colonisation of the individual by the community, providing a framework for resistance against the tendency of certain forms of modern social organisation (as outlined by Marcuse) to suppress dissent and individual agency. It would, as such, be a democratic solidarity.

The number and type of changes required in order for this to occur have been detailed above. It is not a simple task. However, this kind of understanding of science and the attendant solidarity it may produce are preferable both in terms of their faithfulness to the actual realities of scientific practice and their potential impacts on democracy.

CONCLUSION SCIENCE COMMUNICATION IN THE 'POST-TRUTH' AGE

"You're saying it's a falsehood; Sean Spicer our press secretary gave alternative facts"

KELLYANNE CONWAY, COUNSELLOR TO THE PRESIDENT OF THE UNITED STATES OF AMERICA, 22ND JANUARY 2017

'Post-Truth' and Post-Modernism

On Friday January 20th 2017, Donald Trump was inaugurated as President of the United States of America. On a cold and overcast morning, live television coverage appeared to show meagre crowds had turned out to witness the investiture of the United States' 45th premiere – many of the makeshift grandstands lining the presidential parade route were sparsely populated and crowds on the National Mall appeared thin. However, following the inauguration, in his first meeting with the Central Intelligence Agency (CIA), President Trump claimed to have attracted an inauguration crowd of between 1 and 1.5 million (Ackerman and Siddiqui 2017). On Saturday 21st January President Trump's Press Secretary, Sean Spicer, in a heated press conference reasserted President Trump's claim, going on to state that the inauguration had attracted "the largest audience ever to witness an inauguration, period, both in person and around the globe" (Hunt 2017). In the interim, aerial photographs of the crowd on the National Mall (taken by the United States National Park Service) had emerged and were displayed nationally and internationally in newspapers and on television. Comparisons were drawn between the crowd garnered by President Trump and the crowd attracted to the 2009 inauguration of his predecessor Barack Obama. Photographs of President Obama's inauguration appeared to show a significantly larger crowd than had turned out for President Trump's inauguration. Sean Spicer, in the face of such seemingly conclusive evidence of its inaccuracy, nevertheless continued to claim that Presidents Trump's inauguration had been the best attended in United States' history. On Sunday the 22nd, Kellyanne Conway, Counsellor to the President of the United States, appeared on *Meet the Press,* a current affairs programme broadcast on the American television network NBC. In response to the host Chuck Todd's question about the reasoning behind Sean Spicer's claims, and his refusal to admit to their untruthfulness even in the face of photographic evidence, Conway gave her now infamous defence:

> "You're saying it's a falsehood; Sean Spicer our press secretary gave alternative facts" (Conway 2017)

"Alternative facts" has since become a defining phrase of the Trump administration. It summarises an attitude underpinned by a relationship to knowledge which appears quite different from that which proceeded it, an attitude characterised by a quite brazen (and therefore seemingly new) dismissiveness of the evidence and expertise of traditional knowledge authorities.

It is an attitude that has facilitated the appointment of individuals prominent in the variously described 'climate-sceptic' or 'climate change denial' movement to the high offices of the US government. None are less prominent than Mike Pence, President Trump's Vice-President, who once described climate change as a 'myth' (Atkin 2017). Scientific institutions have similarly felt the effects of the legitimising in the political sphere of disregard for scientific knowledge. In the months after President Trump's inauguration, reports (e.g. Smith 2017) appeared detailing the removal of information and resources used by local government in their efforts to tackle man-made climate change from the website of the US Environmental Protection Agency.

The removal of this scientific advice, however, is justified by an attitude which equates scientific knowledge with any other kind of knowledge – a world view in which the epistemological playing field is entirely level. This is an attitude which President Trump has appeared to endorse. Prior to his election, Donald Trump expressed views on climate change at odds with the scientific consensus on the matter. He claimed (via the social media platform Twitter) that;

> "The concept of global warming was created by and for the Chinese in order to make U.S. manufacturing non-competitive." (Trump 2012)

This tweet suggests an understanding that equates science entirely with politics. Science here is a stooge in service of a foreign power, a tool that has been used to further the interests of one nation at the expense of another. Scientific knowledge, as understood here, is purely political. Understood in this way, rejection of climate change, vaccination, or any item of scientific knowledge, set of scientific ideas or piece of scientific advice is an explicitly political act as the creation of scientific knowledge is essentially political. If science is purely political its acceptance or rejection is a matter of choice, a choice analogous to the choice between political candidates or parties.

This political attitude can claim, it appears, intellectual support from STS/SSK analysis in which the equating of science with politics has a relatively long and influential history (e.g. Latour 1983, 1988). Indeed, in the aftermath of President Trump's election, critics were quick to lay the blame for the emergence of the post-truth political world at the feet of so-called 'post-modern' academics (e.g. Calcutt 2016). These academics, it was argued, were involved in the deconstruction of the 'grand truths' of modernism, a fundamental aspect of which was the belief in the objectivity of science. The emergence of post-modernism, this kind of critique claims, laid the foundations for the emergence of post-truth.

It is clear that there are parallels between post-modernist, sociology of knowledge and science and technology studies' analysis of science and the political attitude which legitimises 'alternative facts'. However, laying the blame for the latter at the feet of the former is not justified in the critiques which emerged in early 2016. Nowhere is it made clear how the SSK/STS or post-modern analysis made the leap from niche academic pursuit to intellectual foundation for a political attitude identifiable in much of the western hemisphere (if not beyond). Donald Trump did not discuss his views on Lyotard, Derrida or Latour on the campaign trail. "Science is politics by other means" was not the chant heard at Trump's presidential rallies. Though the parallels are apparent, the nature of the link between the 'post-modern' deconstruction of science's epistemological status and the political legitimisation of the brazen rejection of evidence is far from clear.

A much more probable cause for the widespread political legitimisation of the 'post-truth' attitude is the kind of religious representation of science detailed in chapter six. In chapters seven and eight I discussed the consequence of this representation being taken seriously and a widespread sanctification of science occurring. What the emergence of the post-truth political climate signals is the consequences of the undermining of this sacred representation by real-world experience. Public-facing media representations of science which present science as certain and able to explain everything about the world promote an understanding of science as certain and able to explain everything. These representations are likely to facilitate the expectation that science can and will provide definitive solutions to all societal problems.

However, science is not a definitive solution providing endeavour. Internal scientific controversies arise, scientists disagree on the outcome of experiments. Scientists are often unable to readily state the best application of a new piece of technology, or the best policy to introduce in regards to some new piece of scientific thinking. In just the past decade, scientific experts have repeatedly been shown to be unable to provide definitive, complete solutions to the problems of modern society.

Repeated failure to provide the definitely correct solutions promised by sacred representations of science undermine the image of scientific certainty sacred representations promote. Disregarding the contribution of scientists, and rejecting their advice, is far easier to justify if they are expected, yet repeatedly fail, to provide solutions which are definitive and certain. The failure of science to live up to its sacred image legitimises a lack of trust in science. It is not unreasonable to expect citizens of western societies to react to the repeated failures of science to live up to its sacred image with disillusionment.

It is this kind of attitude that, in the run-up to the UK's Brexit referendum of June 23rd 2016, Michael Gove, co-convenor of Vote Leave (the leading pro-Brexit organisation) and at the time Minister of Justice, was tapping into. The Vote Remain campaign, wanting to maintain Britain's membership of the EU, had enrolled a variety of experts – political, legal, economic, and environmental – to argue the case against Brexit. Warnings of the potentially severe negative consequences of leaving the EU were voiced by well-informed, knowledgeable and credentialed experts. During the pre-referendum campaign, however, Michael Gove claimed in a televised interview with Sky News correspondent Faisal Islam that the British public "have had enough of experts".

Gove's statement appeared to be emblematic of the trend in public opinion that attributed the social, political and economic problems of British society to the failures of experts. Expert stock-brokers and bankers invested in sub-prime mortgages which led to the collapse of the housing bubble, fuelling the financial crash of 2008. Expert economists and political technocrats had pushed the agenda of globalisation that allowed for increased immigration, fuelling the stagnation of wages and increasing underemployment. These same experts had done little to remedy the tangible drop in living standards which accompanied the 'Great Recession'.

This direct experience of the continued and prolonged failure of experts is in direct contradiction to the scientific perfection promised in the religious representations of science. Experts had promised the world, but ended up causing, and failing to solve, many real-world problems. When viewed in these terms, continuing trust in experts was at best misplaced, at worst downright counter-productive. On the 23rd of June, the British public voted to leave the European Union.

The negative consequences, both for science and our society, of the post-truth political climate are in the process of playing out. A total loss of respect for science results in the questioning of the utility of science. If science's practical utility appears reduced, its social necessity could be questioned. A reduction in public and financial support for science will follow. This process can be seen to be occurring in the Trump administration's treatment of the EPA. In the long-term, this continuing undermining of science will adversely impact the scope and quality of scientific research. Science will be able to address fewer and fewer problems and could eventually atrophy to a state of practical uselessness.

It is the problematic consequences of the 'post-truth age' and its opposite the *Society of Sacred Science* that lend urgency to my research. Public understanding of science is shaped by media representation. Knowing the impact media representations have on public understanding, the need to understand how and why these media representations appear as they do becomes of primary concern. Through understanding these processes changes can be suggested, as it is in working to change these media representations of science that some of the extremes of the 'post-truth age' and the *Society of Sacred Science* can be avoided.

Production

To understand where problematic representations of science come from, and to offer suggestions as to how they can be avoided in future, non-fiction science television production must be understood. In chapters four and five I detail this production process. In chapter four I provide a sketch of the production process of a non-fiction science programme. This is necessarily brief and compound in its nature, pieced together as it is from the various accounts of the production process received during my fieldwork amongst science television programme makers. I then highlight the various pressures and tensions felt by individuals inhabiting the different roles at the different stages of the production process and the differing aims and responsibilities each role brings with it. I do this in order to highlight the shared underlying aspirations of the form-of-life of non-fiction science television making, and the knowledge that is dispersed and reinforced through the community and practises that are engaged in by members to uphold these values. It is out of these shared values and practises that representations of science emerge.

Non-fiction science television makers want to have their programmes watched by as large an audience as possible. This is fundamental to the practise of all television programme making, and non-fiction science television is not immune from this. Gaining as a large an audience as possible means making a programme as engaging as possible. Embedded within a non-fiction genre, however, science programme makers also must produce programmes that have a basis in reality. Science programme makers feel a responsibility to their audience to produce programmes which have a basis in fact, as programme makers believe their audiences expect the content of non-fiction science programmes to be factual. Therefore, the options for producing engaging programmes are limited compared to other genres. Outright fabrication runs counter to the faithfulness to reality demanded by genre, however, achieving a large, engaged audience is of the most fundamental importance to the science film-maker.

This process is further complicated by the fact that different channels and different time slots bring with them different audiences who must be engaged in different ways. Therefore, film-makers are engaged in practises which facilitate the production of films which have a basis in reality and yet are tailored to engage these diverse audiences. What this amounts to, in these different films which cater to different audiences, is a manipulation of some aspects of scientific reality and a fidelity to others.

In long-form science documentaries, the highest prestige format, what counts as faithful representation of scientific reality is faithful representation of scientific facts. Representation of the context of the production of these facts does not require the same level of fidelity to reality. Indeed, it is through the manipulation of this context of scientific fact production that the drama of a long-form science documentary – and thus its engagement potential – is heightened. This context of production can be made to fit within a narrative structure which provides a closure and certainty which is absent from the reality of science, but perceived as a justifiable and effective method for creating an engaging long-form science documentary. Engaging in this kind of film-making practice is made easier for film-makers as the model of science that is promoted within the film-making community is an undergraduate model of science. This is a model of science where science is viewed as producing stable isolated facts, the context of production of which is irrelevant.

Different times and different channels within the television schedule bring with them audiences with diverse characteristics. Film-makers believe that not all audiences are engaged using the techniques employed in long-form documentary. Some audiences require different strategies of engagement which allow for a fidelity to other aspects of the reality of science. In the early evening (7pm) slot, an audience can devote less attention to an over-arching television narrative, and therefore film-makers utilise shorter-from programmes to engage their audience. Short-form current affairs or magazine-style science programmes engage their audience through their relevance or newsworthiness. Within these genres other aspects of science are foregrounded – its changeability or uncertainty – which tend to be elided in longer-form documentary.

The desire to engage as large an audience as possible is underpinned by at least two concerns. On the one hand is the obvious professional pressure to satisfy the demands of mass media. Getting as large an audience as possible for a programme helps the film-makers involved in the production acquire their next job. However, a more subtle yet no less influential aim also drives this desire. Non-fiction science film-makers as a group see the communication of science as an inherently good thing. There is a normative element to their film-making. Non-fiction science film-makers believe that the public should know about science, and that through their film-making they are providing a necessary and beneficial public service. Science programme-makers' understanding of their role in society is built on a naïve philosophy of science which views science as a truth-making certainty machine *par excellence*. It is this understanding that further allows, and encourages, science film-makers to produce uncritical representations of science, including representations which attribute to science religious characteristics. What makes the religious representation of science so problematic is that it is best facilitated in long-form documentary programmes. These kinds of programmes are the most prestigious, most often broadcast in the prime 9pm slot, and therefore tend to reach a large and more engaged audience. The religious representation of science is therefore potentially a highly influential representation, which has the potential to create a public understanding of science which hampers the proper functioning of democracy.

Representation

In order to show how science can be represented *like* a religion, I demarcate the two. I argue that both science and religion are essentially social. The knowledge and understanding produced by each rest on a similar cultural foundation. It is erroneous to claim that scientific knowledge or understanding is epistemologically superior to religious knowledge or understanding. However, and despite this, I argue that it is still possible to demarcate science from religion, and do so through contrasting the formative aspiration of each social practice. Though science and religion share a number of formative aspirations, and adopt formative aspirations that are different yet unopposed, there are a number of formative aspirations that are in direct contrast in each form-of-life. Specifically, science is defined by aspirations to open-endedness, empiricism, organised scepticism, and bounded generality. Religion on the other hand is defined by aspirations to closed-endedness, anti-empiricism, total generality and thus meaning provision and organised faith. Along these lines clear boundaries can be drawn between the scientific and the religious form-of-life. Thus it is justifiable to claim that science can be presented like a religion.

To illustrate this, I analyse two non-fiction science programmes which emerge from the complex production process described in chapters four and five, showing how the representation of science within each is markedly distinct. In the long-form BBC Two 9pm documentary, science is presented like a religion. Science is shown to provide a creation story, be certain and unchanging in its understanding and able to explain everything about the world. Scientific facts are represented as revealed easily with minimal intervention in or processing of the natural world. Science is represented as able to provide meaning. In the 7pm BBC One magazine show the representation of science is more faithful to the formative aspirations of science. Science is changeable and changing, requiring constant revision. Scientific knowledge requires technical skill and equipment in its production; nature must be subject to skilled and expert processes and procedures in order for scientific knowledge to be produced. The results of scientific processes are shown to be ambiguous, potentially both beneficial and/or harmful.

Audiencing

In the final chapters of the thesis, I highlight the potentially undemocratic impacts of the religious representation of science. I first explore the plausibility of the religious representation of science fulfilling a religious function in a modern society. The emergence of mediatised rituals show that collective effervescence can occur on a national scale in modern society. During a mediatised ritual mass media is active in imbuing certain events and forms with ritual significance. Importantly, in a pluralised society in which there is a diversity of beliefs, cultures and sub-cultures, media representations can still provide these sub groups with collective representations around which they can coalesce. With the advent of Social TV – the confluence of social media and television viewing – individual audience members are provided with tangible, real-time avenues through which they can form and maintain connections with one another and thus reaffirm a sense of collective understanding and solidarity. In so doing, audiences may utilise these collective representations as a basis for a foundation of meaning. Indeed, there is some indicative evidence that at least some science film-makers see their role as providing this kind of collective representation and that at least some audience members see science programmes that present science in a religious way as serving this purpose. I therefore argue that it is plausible that the religious representation of science could form the basis for a socially sanctified science.

I then go on to detail the potential consequences of a widespread sanctification of science within a society. If science formed the basis of a society-wide religion, democracy would be undermined. Science would colonise all other institutions and become the only legitimate meaning making institution. This would limit the ability of individuals to critique the social order, as there would be no legitimate alternative standpoint from which to offer critique. This would fundamentally undermine the kinds of freedoms enjoyed in a democracy.

The alternative outcome of the religious representation of science to the *Society of Sacred Science*, as detailed in opening sections of this chapter, is the kind of disillusionment witnessed in the current 'post-truth' political climate. Unfulfilled promises of perfection and certainty can justify a lack of regard for the claims of science. The threat to the democratic institutions in this kind of society is similarly grave to that posed in the *Society of Sacred Science,* with the Trump administrations' treatment of the EPA perhaps a bellwether for a trend the true shape of which we are only beginning to discern.

Sanctified Science, Post-Truth and Elective Modernism

Life in the one-dimensional *Society of Sacred Science* would be fundamentally constrained, as the colonisation of all institutions by an over-reaching science would be total. In the 'post-truth' world, the levelling of the epistemological terrain has led to an equalising of all knowledge positions, rendering claims to the external authority of science illegitimate. The colonisation of science by politics has meant that all claims are of equal worth and the only legitimate decision making means are populist ones. To prevent the rise of the *Society of Sacred Science*, and to alleviate the darkest consequences of the post-truth world, the production of religious representations of science must cease. In order to limit the emergence of the religious portrayal of science different film-making technique could be employed. These techniques would emphasise the social underpinning of science, its inherent incompleteness and changeability. The use of new film-making styles would also encourage the adoption of a different model of science, a model of science shaped by STS and SSK accounts of the scientific endeavour.

Of even greater utility, I argue, the secular portrayal of science could be modified to become an elective modernist portrayal. This portrayal would foreground science's formative aspirations as its defining characteristic. Science understood in this way would be understood as a morally good (but by no means perfect epistemologically) form-of-life for producing knowledge of the world rather than as a perfect truth-making machine. The cultural importance of science would also be recognised, as many of the aspirations of science would be shown to align with the values preferred in a democracy.

A public that adopts the Elective Modernist position would avoid the worst excesses of both the *Society of Sacred Science* and the 'post-truth' age. An Elective Modernist public would not view scientists as soothsayers and would therefore expect advice and guidance not truth and certainty. This public would be able to assess scientific claims meaningfully, understanding the importance of knowledge of the context of these claims' production, and thus hold scientists properly to account, but would be much more forgiving when the advice of scientists was not perfect. Science would retain a central place in modern society, but not because of its relationship to truth. Instead science would be celebrated because of the values which it promoted; values that ensure the freedoms enjoyed in a democracy. Elective Modernism thus provides a middle way between the extremes of the over-zealous respect for science evident in the *Society of Sacred Science* and its alternative devaluing and disregarding that is evident in the 'post-truth' world of President Trump and the purveyors of 'alternative facts'.

Departure points

The extent to which science represented as religion has a religious function is the most obvious departure point for future enquiry. I have only briefly hinted at how individuals react to science presented as religion. How and if these representations of science are utilised (by individuals and groups), whether they produce a sense of solidarity or act as a shield from meaninglessness on a significant scale is yet to be identified.

The forms of science film-making I suggest produce preferable representations may be difficult to implement. The logic of non-fiction science film-making compels film-makers to attract an audience. Techniques for attracting an audience to science television programmes are well-established. That these techniques can lead to the religious portrayal of science is problematic from the perspective I adopt. Whether the arguments I marshal against this kind of representation of science are compelling enough to override the professional and institutional imperatives of science film-making and enact a change within the community remains to be seen.

However, in conducting this research it has become clear to me that the overwhelming majority of science-film makers have a genuine belief in their films' abilities to shape public attitudes and a genuine concern for science and their audience. If my analysis is properly understood, and the potentially negative consequences of the religious representation of science I envisage taken seriously, then science film-makers' aims and my own should align. I am sure, however, that science programme-makers, if their film-making was informed by a more contextual model of science, possess the creative ability to produce programmes which would engage an audience with democratically beneficial representations of science. Indeed, as influential arbiters of public perceptions of and attitudes towards science, science film-makers possess this ability to promote an understanding of science that is beneficial for both science and the public. The elective modernist representation of science is such a representation, the religious representation of science is not. For the benefit of science, and the public, religious representations of science must not be produced.

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APPENDIX 1

The following appendix contains transcripts of each of the two episodes of *Wonders* and *Bang* which I analysed in detail. The transcripts provide an accurate record of the talk in each programme. This record of the talk is presented alongside my description of the visual and non-talk soundtrack elements. I described what appeared most relevant in each visual cut and noted when prominent soundtrack changes were made.

Wonders of Life Episode 1 Transcript

00:00 – 01:00: shot of close up of an insects eye, cut to insect larva holding on to stem of plant, cut back to close up of eye, Brian Cox voiceover begins – "this creature is a wonder of life" – cut to insect catching another insect and eating it – "a voracious predator, this male has lived underwater for nearly five months, feeding, growing, preparing for this moment" – cut to insect climbing up river bank – "he's about to undertake one of the most remarkable transformations" – cut to close up of insect emerging from chrysalis - "in the natural world, from aquatic predator" – closer shot of insect emerging - "to master of the air" – shot of insect fully emerged with tail extending, close up of insects head, jaws flexing, shot of wings expanding

1:00 - 02:03: continued shot of wings expanding, shot of insect on branch, graphic of insects name in English and Latin, English in normal script Latin in italics reads 'Dragonfly/Anisoptera', changes colour form green to red (possibly time lapse footage) cut to shot of man (Brian Cox) walking by a lake/pond, natural setting, shot across pond through leaves of a plant, close shot of Brian Cox walking, from behind, yet to engage with camera, close up of insect wings, Brian Cox voiceover – "the brief adult life of a dragonfly is amongst the most" – close up of red-thing –possibly segment of dragon-fly tail, flexing slightly – "energetic in nature" –cut to slow-motion shot of dragonfly taking flight from branch, cut to Brian Cox squatting in front of pond, once again shot through the leaves of another plant delivers piece to camera – "dragonflies are one of the most remarkable animals, you can see there incredible agility in flight, just watching them skim across" – cut to shots of dragonflies flying across pond surface – "the surface of this pond, they can pull 2 and a half g in a turn and they can fly at fifteen miles an hour" – cut back to Brian Cox in front of pond – "which is fast for something that big" – Brian Cox holds is to index fingers about 4/5 inches apart, cut to slow-motion shot of dragonfly landing on branch, initially out of focus, comes into focus, has graphic label which reads 'wings: 50 beats per second', Cox voiceover - "they've been around on earth since before the time of the dinosaurs and in that time they've been fine-tuned by natural selection to do what they do which is to catch their prey on the wing"

02:04 – 02:58: close up shot of dragonfly head, graphic label appears connected to the eye of dragonfly reads '360 degree vision', close up shot of wings of dragonfly, close up of its legs gripping a bit of wood, close up of hits head with legs wiping its eyes, cut to Brian Cox standing behind dragonfly on bit of wood, dragonfly in focus Cox out of focus, begins – "so dragonflies are beautiful pieces of engineering" – Cox brought into focus, dragonfly goers out of focus – "they're intricate, complex machines, but is that all they are?" – cut to shots of dragonflies flying around bit of wood in pond, Cox voiceover – "because once their brief lives are over" – close up of dragon fly on branch, flies away – "their vitality will be gone"- shot of dragonfly hovering, shot of dead dragonfly in water, fade to closer shot of dead dragonfly, choral singing begins in soundtrack – "and this raises deep questions" – fade to bright light/explosion accompanied by gentle explosion noise on soundtrack, cgi of what could be a star, fades to shot of the sun seen through water with jellyfish in between camera and surface – "what is that makes something alive?" – cut to shot of Brian Cox in profile, looking into distance, away from camera in forest/jungle, with tree full of birds/animals behind him, then turns to look at tree, watches bird fly off camera –"and how did life begin?" – Close-up of orangutans face – "in the first place?"

02:59 – 03:27: shot of leafy vegetation, with out of focus vegetation in foreground, cut to close up of Brian Cox's face, delivers piece to camera – "so what is the difference between the living and the dead, what is life?" – choral singing soundtrack becomes more prominent, possible key change, sounds inspiring/uplifting, slow-motion shot of dragonfly taking flight from branch, cut to cgi/microscope image of round things (could be cells) one expands, cut to close up of this and the circumference is made up of what look like chemical bond drawings, reminiscent of DNA, inside circle is close up of ants and word 'wonders' appears, then cut to close up of lions eye inside circle, words 'of life' appear, cut to closer version of previous shot of sun through water with jellyfish, circle with bond circumference rapidly expands and words 'wonders of life' are left on screen with jelly fish,

03:28 – 04:00: cut to close shot of virgin Mary statuette on a car dashboard, graphic with words 'what is life?' appear , soundtrack kind of middle-eastern/African woman vocal singing, cut to shot of Asian men riding on top of and on the back of a minibus, shot form another moving car, shots from car of waterfall seen through tree's, cut to Brian Cox in aviator sunglasses riding in back of car looking out of window at surroundings, voiceover begins – "I've come to one of the most isolated regions" – shot from car of approaching bridge – "of the Philippines" – shot of minibus travelling over rutted gravel road – "to visit the remote hilltop town Sagada" – shot of bus travelling uphill from opposite side of small valley, urgent guitar music as soundtrack, shot of Brian Cox in minibus, voiceover continues – "it's a two day drive from the capital Manilla" – shots of Brian Cox being bounced around in back of bus, attempting to take photograph out of window and laughing when he can't – "over some of the countries roughest roads that wind their way" – shot of minibus driver – " 1500 metres up into the hills" – shot of land sloping away beneath road and other hills in the distance

04:00 – 05:06: - shot of Brian Cox closing minibus door in town, shot of crowds of people, children dressed up in costumes, rabbit ears , shot of lone child in skeleton costume, shot of Brian Cox walking up street away from camera, shot of Cox's feet climbing stone steps, shot of Brian Cox walking past camera with lush forest/vegetation and hills in background, town just visible, graphic label appears, reads 'Sagada, Philippines, population:10,930', urgent guitar music with singing in a foreign language continues, shot of Brian Cox walking down hill towards camera away from setting sun, which haloes him with lens flare, voiceover begins – "this is a place where the traditional belief is that mountain spirits" – shot of wooden boxes with crucifixes on them mounted on large wall – "give us life and that our souls return to the mountain" – shot of Brian Cox in profile, lit by setting sun, looking out off camera – "when we die" – more shots of wooden boxes, this time with wooden chairs attached, shot from below, give sense of vertigo/strangeness to image, with a slow zoom adding to the effect – "and where the people who live here still imagine that the spirits of the dead" – shot of Brian Cox walking away from box wall – "walk among the living" – shot of child with crowd of people behind her walking uphill towards camera, shot of man with a bundle of sticks over his shoulder, shot of girl lighting candle and placing it by gravestone next to bundle of sticks, Brian Cox voiceover begins – "tonight is November the first and" – cut to Brian Cox walking up hill with other on paths, delivers piece to camera – "and here in Sagada, in fact across the Philippines that means that it's the day of the dead. That's a day when people come to this graveyard on a hillside and well celebrate the lives of their relatives

05:07 – 06:00: shot of person holding a candle, pull back to person under umbrella guarding candle flame from rain, shot of man poking fire with a stick, Brian Cox voiceover – "the people light fires to honour and warm the departed" – shot people in in front of fire in front of gravestone – "inviting their souls to commune with them" – shot of Brian Cox walking through graveyard at night with lots of fires and smoke and people, camera following behind him as he looks around with interest, shot of man with bucket and wand flicking water, priestly actions, shot of various groups at different grave fires, shot through a prominent fire in foreground, obscuring/blurring parts of the scene, shot of crucifix in foreground with out of focus fire and people behind it, cut back to Brian Cox in graveyard delivers piece to camera – "now no matter how unscientific it sounds this, this idea that there is some kind of soul or spirit or animating force that makes us what we are and that persists after our death is common, virtually every" - shots of children at grave fires – "culture every religion has that deeply held belief" –

06:01 – 7:04: shot of family group around grave fire, Cox voiceover – "and there's a reason for that because" – cut back to Cox - "it feels right. I mean, just think about it, it's hard to accept that when you die you will just stop existing and that you are, your life, the essences of you is just really something that emerges from an, an inanimate bag of stuff." – cut to shot of fire in front of gravestone, shot of graveyard from a distance with crucifix prominent in foreground and then many different fires dispersed throughout graveyard, subtitles appear, read 'I believe that their spirits are around us' – cut to shot of young woman being interviewed, talking and subtitles of what she is saying which read 'I know that they are near'. 'that they have a second life', - shot over the shoulder of Brian Cox looking out across graveyard with fires, more subtitles 'we talk to them silently… - Brian Cox turns to ¾ profile to look behind where the camera is facing, but not at camera, middle distance shot of children round grave fire, shot of Brian Cox lighting candle at grave with large smile on his face, he is lighting a candle with a young child, says to the child – "not too close" – then when the child has lit the candle "hurray" – shots of families around grave fires smiling as Brian Cox takes photo of them

7:05 - 7:40: shot of Cox in grave yard, delivers piece to camera - "you can see that these people feel not only that they're going to celebrate the lives of their relatives, but they're coming in some sense, to, to, to communicate with them, their relatives even though their physical bodies have died are still in some sense here" – shot of group of people silhouetted against sky lit up by grave fires, Cox voiceover – "And when you think about it that's not so easy to dismiss" – shot of children tending grave fire - "I mean, if we are to state that science can explain everything about us" – cut back to Cox - "then its incumbent on science to, to answer the question what is it that animates living things, what is the difference between err, a piece of rock that's carved into a grave stone and me?" – shot of two graves with fire in front of them, cut to out of focus shot of Cox in profile which slowly focuses on him looking into distance, shot of family group standing under umbrellas

7:47 – 8:09: "for millennia some form of spirituality has been evoked" – close up of grave stone with one candle burnt low still lit on it – " to explain what it means to be alive – "cut to shots of fires, one very close to camera which almost fills the screen – "and how life began." Cut to time lapse footage of grave yard with fires burning and people moving in and out – "It's only recently that science has begun to answer these deepest of questions." – fade to a CGI image of the earth with various bits of landmass lit up in different place, sun just rising on the horizon (C S)

08:17 – 09:41: cut to shot of outside of café, cut to Brian Cox inside building reading, shot of book being read, cut to a wider shot of Brian Cox drinking from a cup and reading in Asian looking café, low tables, wooden, cut to Cox, delivers piece to camera – "In February 1943 the physicist Irwin Schrodinger gave a series of lectures in Dublin. Now Schrodinger is almost certainly most famous for being one of the founders of quantum theory but in these lectures, which he wrote up in this little book" – Cox holds book up to camera, title is 'what is life?' – "he asked a very different question, what is life? And right up front on page one, he says precisely what it isn't, it isn't something mystical, says Schrodinger, there isn't some magical spark that animates life, life is a process, it's the interaction of matter and energy described by the laws of physics and chemistry, the same laws that describe the falling of the rain or shining of the stars." - Cut to shot of two men playing chess, shot of minibus driving past with man riding on the back, shot of people on balcony - "So the question is, how is it that this magnificent complexity" – shot of people in street, cars being ridden by men, cows in the background – "that we call life could have assembled itself" – cut back to Cox in café – "on the surface of a planet which itself formed from nothing more than a collapsing cloud of gas and dust?

09:42 – 10:34: shot of Cox leaving café, voiceover – "to Schrodinger, the answer had to lie in the way living things process" – shot of Cox outdoors in profile, looking of camera – "one of the universes most elusive properties" – shot from behind Cox, silhouetted against out of focus hills –"energy" – shot Cox walking through forest away from camera, hot of dog asleep, graphic label appears reads 'sleeping dog/48.5 joules/second' , shot of child behind fence, graphic label reads 'Child's Brain/ 11 Joules/second', shot of Brian Cox walking over bridge, graphic label reads 'Walking/11.5 joules/second', wide shot of Cox walking across bridge, stops in middle, voiceover begins – "energy is a concept that's central to physics" – cut to Cox sitting by river delivers piece to camera – "but because it's a word that we use every day its meaning has got a bit woolly, I mean it's easy to say what it is in a sense, I mean obviously this river – points at the river behind him – "has got energy because over the decades and centuries its cut this valley through solid rock"

10:35 – 12:29: wide shot of lush valley with river at bottom, voiceover – "but while this description sounds simple, in reality things are a little more complicated"- closer shot of the river, cut back to Cox by river _"for me the best definition is that it's the length of the space-time four vector" – graphic appears with equation- "in the time direction, but that's not very enlightening, I'll grant you that" – close up shot of flowing river, shot of rapids , shot of Cox walking down a hill, voiceover – "over the years the nature of energy has proven" – shot of Cox crossing stream – "notoriously difficult to pin down" – shot of rapids – "not least because it has the seemingly magical property that it never runs out" – shot of waterfall – "it only ever changes from one form to another" – close up of waterfall, shot of Brian Cox standing in front of camera with waterfall in background – "so take that waterfall, at the top of the waterfall it's got something called gravitational potential energy which is the energy it possesses due to its height above the earth's surface. See, if I" – bends down to collect water in beaker – "scoop some water out the river with this beaker then I'd have to do work to carry it up to the top of the waterfall, I'd have to expend energy to get it up there, so it would have that energy as gravitational potential" – shot of water falling from top of falls, voiceover – "I can even do the sums for you; half a litre of water has a mass of half a kilogram multiplied by the height so that's about 5 metres and it's acceleration due to gravity is about 10 metres per second squared so that's half times 5 times 10 is err 25 joules, so I'd have to put in 25 joules to carry this water to the top of the water fall, then if I emptied it" – shot of Cox emptying beaker – "over the top of the waterfall then all that gravitational" – close up of water falling from top of falls – "potential energy will be transformed into other types of energy. Its sound which is pressure waves in the air" – cut back to Cox making in and out motion with his hands to show pressure waves – "there's the energy of the waves in the river" 0 makes sweeping waving motion with his hand – "and there's heat, so it will be a bit hotter down there" – indicates bottom of waterfall – "because the waters cascading into the pool at the foot of the waterfall.

12:30 – 13:43: "But a key thing is energy is conserved, it's not created or destroyed" – shot of water falling into pool, voiceover – "so because energy is conserved, if I was to add up all the energy in the water waves – cut back to Cox – "all the energy in the sound waves, all the heat energy at the bottom of the pool, then I would find that it would be precisely equal to the gravitational potential energy at the top of the falls" – cut to close up of waterfall, voiceover – "what's true for the waterfall, is true for everything in the universe" – shot of water falling into pool – "it's a fundamental law of nature" – shot of sun setting over misty, unfocused landscape, lens flare creating halo around image – "known as the first law of thermodynamics" – Cox is brought into focus looking away from camera in middle distance, halo remains around image, he steps up onto a small hillock and is in the middle of the image haloed, voiceover continues – "and the fact that energy is neither created nor destroyed" – shot of Cox ¾ profile with setting sunlight on his face, looking into distance – "has a profound implication, it means energy is eternal" - cut to shot of sun setting over hills, soundtrack with uplifting piano music becomes more prominent. "The energy that's here now" – cut to Cox delivering piece to camera, setting sun over his right shoulder creating a halo of lens flare around him - "has always been here and the story of the evolution of the universe is just the story of the transformation of that energy from one from to another, and the origin of the first galaxies to the ignition of the first stars and the formation of the first planets." -

13:43 - 15:14: CGI shot of explosion, music again prominent, cgi shot of glowing, pulsing cloud, voiceover – "every single joule of energy" – another CGI explosion of star – "in the universe today was present at the big bang, 13" – another CGI explosion, representing big bang – "point 7 billion years ago. Potential energy held in primordial clouds of gas and dust" – CGI image of early galaxy, bright centre with dusty cloud surrounding it –" was transformed into kinetic energy" – dust sucked into centre making it brighter – " as they collapsed to form stars" – another bright flash followed by close up of flaming clouds, which becomes sun like object – "and planetary systems just like our own solar system" – star explodes then visualisation of rushing through hot clouds of gas, another star forms, another explosion – "in the sun, heat from the collapse" – cut to a more familiar close up image of sun - "generated fusion reactions at its core" – shift to ultraviolet image of sun, wider shot of it forming at very high speed, slowed shot of early planet in dusty solar system with lots of smaller bits of solid debris – "hydrogen became helium, nuclear binding energy was released heating the surface of the sun, producing the which began to bathe the young earth". – shot of red ball (sun/planet) with glowing spot yellow on it, cut back to BC haloed by sunlight – "And at some point in that story, around 4 billion years ago, that transformation of energy led to the origin of life on earth." – cut to shot of sun sinking below hill and then fading to black

15:15 – 16:47: close up of small waves lapping against shore, shot of man on raft on lake, silhouetted against backdrop of hills, twilight, Cox voiceover begins – "around 350km south of Sagada, this is Lake Taal"" – wider shot of man on raft shows cloud formation above lake, blocking sunlight, beautiful, impressive natural shots, shots of men fishing from boats – "despite its sleepy, languid appearance, this landscape has been violently" – wider shot of men fishing, shot mostly of sky, dwarfs men, adds to majesty of nature – "transformed by energy" – shot of outrigger of moving boat, taken from boat, wider helicopter shot of boat moving across lake, lush forested hills behind, cut back to boat and shots of other outrigger, shot of Brian Cox on boat in profile looking off camera, shot of birds flying off lake surface as boat approaches, cut to Brian Cox at front of boat, delivers piece to camera – "when I think of a volcano I usually think of a pointy, fiery mountain with a little crater in the top, probably a bit like that one" – points to approaching island – "but actually this entire lake is the flooded crater of a giant volcano. It began erupting only about 140 thousand years ago and in that time it's blown 120 billion cubic metres of ash and rock into the earth's atmosphere. Now this crater is 30km across and in places 150m deep I mean that's a, that's a cube of rock 5km by 5km by 5km just blown away

16:48 – 17:48: helicopter shot of boat travelling across lake, cut back to Cox on boat – "that's a big volcano" – cut to helicopter shot flying over village on lake shore, helicopter shot of Cox disembarking from boat, voiceover begins - "Taal lake is testament to the immense power" –cut to shot of Cox walking up jungle path towards camera – "locked within the earth at the time of its formation" – different shot of Cox walking up path, from side through trees, wider shot of Cox higher above the lake, with large expanse of lake behind him, cut to cgi large bright explosion, star formation graphic, then shots of molten world, then close up of larva bubbling, voiceover begins – "since the lake was created" – cut to high helicopter shot of island in middle of lake with a smaller lake inside it – "a series of further eruptions formed the island in the centre" – shot of Cox in profile, looking off camera – "and at its heart is a place where you can glimpse" – cut to helicopter shot rising up the side of the island to reveal the inner lake – "the turmoil of the inner earth, where energy from the core still bubbles up to the surface" – shot of lake shore, barren and rocky steam pouring of it and water bubbling, different shot of mud bubbling on lake shore, shot of steam coming from vent in rock – "producing conditions similar" – shot of Cox walking through lush green vegetation, cut to shot from behind him looking out over lake – "to those that may have provided the very first spark of life."

17:50 – 19:05: shot of steam rising up rock face, shot of lake rocky barren lake shore, steaming, with lush hills in background, shot from low of Cox walking along shore away from camera, close up of bubbles on water, cut to Cox, delivers piece to camera – "now the water in this lake is different from drinking water in a very interesting way, see if I test a bottle of water with this, which is called universal indicator paper" – pull back to Cox leaning against rock on lake shore, beaker next to him, holding bottle of water, holds up bunch of pieces of indicator paper , takes one, dips it into bottle – "then see immediately that it goes green" – close up of paper against blue sky, is has turned green – "and that means that its completely neutral, it's called ph7 in the jargon, then look" – shot of Cox dipping beaker into lake – "what happens when I test the water from the lake" – dips paper into beaker of lake water - "now the indicator paper stays orange, in fact" – holds it up to camera – "it might have gone a bit more orange" – close up of paper with Cox's face out of focus behind it – "so that means that this is acid, it's about" – different angle close up – "ph3" – shot of lake bubbling and rocks steam with camera half submerged, then is lowered to bottom of shallow part of the lake with bubbles streaming past, voiceover – "at the most basic level the energy trapped inside the earth is melting rocks" – cut back to Cox on lakeshore, pats rock he is leaning against – "and when you melt rock like this you produce gases, a lot of carbon dioxide, now in the case of this volcano" – graphic appears , reads SO2/sulphur dioxide' – "a lot of sulphur dioxide. Now sulphur dioxide dissolves in" – graphic appears below first one, reads 'H20/Water' - "water and you get - two graphics melt into each other, leaving just chemical letters, read 'H2SO4' – "H2SO4, sulphuric acid

19:06 – 20:12: shot of large bubbling patch of water, middle hot of lakeshore and hills in background, voiceover – "now what do I mean when I say that the water is acidic?" – cut back to Cox, piece to camera – "well water is H20, hydrogen and oxygen – "Cox holds hand up about a foot apart, graphic appears in between them reads 'H2O – "bonded together" – graphic changes to show two H's joined to and O with small lines – "but actually when its liquid it's a bit more complicated than that, it's actually a sea of ions so H+ ions" – Cox holds hand up and graphic of H+'s appear – "so that's just single protons, and OH minus" – OH- graphics appear on other side of screen – "ions so that's oxygen and hydrogen bonded together, all floating around" – both graphics wobble slightly, suggesting floating – "now when somethings neutral, when the ph. is 7, that means that the concentration of those ions are perfectly balanced" – Cox holds hands level with each other, the OH- and H+ graphics are of equal number on the screen under his hands and are grouped together equally, balancing each other – "when you make water acidic then you change the concentration of those ions" – a couple of the OH- graphics pop and disappear and are replaced H+ graphics, the OH- ions are also lower on the screen, matching Brian Cox's hand position- "to be specific you increase the concentration of the H+ ions" – Cox raises his hand and the H+ graphics move up with it – "of the protons" – shot of bubbling lake with scum floating on surface – "so this process of acidification" – cut back to Cox" - has stored the energy of the volcano as chemical potential energy" – cut to helicopter shot of island with lake in the middle

20:13-21:37 – "the volcano transforms heat from the inner earth into chemical energy" – shot of Cox walking along rim of inner lake crater – "and stores it as a reservoir of protons in the lake" – cut to shot of liquid being poured into beaker, beaker on muddy earth with twigs around it (20:25 – begins to show BC preparing an 'experiment' to show how batteries work) "and this is the same way the energy is stored in a simple battery" – shot of lid being unscrewed off bottle - "or fuel cell" – shot of small amount of liquid from bottle being poured into liquid in beaker, same shot but from above and close up (combines 2 liquids in a beaker – not told what liquids are) - "these bottles contain" – shot of Cox pouring contents of beaker into a bottle which is attached to another bottle at its side, both bottles are in a glass dish – "a weak acid and are connected by a semi permeable membrane." – as liquid fills one bottle it can be seen filling the other one – " Passing an electric" – close up of two batteries connected together with small bits of wire, looks shoddy - "current through them has similar effect" – shot of crocodile clips being connected to black things protruding from tops of bottles - "to the volcanoes energy bubbling up into the lake - shows bottles with lengths of black material immersed in liquid which is bubbling inside them, cut to close up of length of black material, surrounded by bubbles, overlaid with H+ graphics – "it causes protons to build up in one of the bottles." – cut to Brian Cox, piece to camera - "You can think of it, I suppose, like a waterfall, where the, the protons are up here waiting to flow down and all you have to do to release that – "wider shot of Cox kneeling on crater rim with equipment in front of him - "energy and do something useful with it is complete the circuit, which I can do – "unclips crocodile clips, close up of bottles - "by just connecting a motor to it" – picks up motor and attaches it to bottle tops, close up of motor spinning - "there you go, look at that, that's the protons cascading down the waterfall and driving the motor round" – another close up of motor in Cox's hands spinning, cut to wider shot of Cox behind equipment - "it actually works (laughs at camera)" – another close up of the motor – "remarkable actually."

21:37- 22:27: "Now the fuel cell" – cut to shot of Cox, delivers piece to camera – "produces and exploits its proton gradient artificially but there are places on earth where that gradient occurs completely naturally, here for example" – wider shot, Cox indicated lake in background – "so we've got the proton reservoir over there the acidic, volcanic lake, look that way" – camera pans to indicated larger lake – "and there's another lake, and the reaction of the water with the rocks on the shore make that lake slightly alkaline, which is to say that there's a deficit of protons down there , so , here's the waterfall, a reservoir of protons up there the deficit down there, if you could just connect them, then you'd have a naturally occurring geological fuel cell" – cut to close up of Cox _ "and its thought that that the first life on our planet may have exploited the energy released in those natural proton waterfalls"

22:28 –23:27: helicopter shot of island with lake in middle of lake, shot of Cox walking down mountain path, shot of old Asian woman on balcony through leaves, shot of boys playing with a ball, shot of Cox walking into a lakeside town, shot of mother and baby on boat, shot of Cox in bamboo made building, opening iPad case, shot of local people sitting with nets in bamboo structure, lake in background, shot of local children intently watching Cox use his iPad, out of focus shot from child's perspective, Cox holds iPad up and asks – "what do you think?, its good ain't it?" – shots of children looking at Cox, who is off camera, smiling, embarrassed, shot of Cox watching a video on his iPad, shows video to camera, video of irregular white structure against a dark background, cut to Cox, delivers piece to camera – "these are pictures from deep below the surface of the Atlantic ocean somewhere between Bermuda and the canaries and it's a place known as the lost city" – cut to shot of images on iPad – "you can see why, look at these huge towers of rock, some of them 50 60 metes" – cut back to Cox – "high reaching up from the floor of the Atlantic and in to the ocean"

23:28 –25:19: video footage of underwater rock formation, voiceover – "and its what's known as a hydrothermal vent system, so these things are formed by hot water and mineral and gases rising up from deep within the earth," - cut back to Cox – "but the reason its though that life on earth may have begun in such structures is because these are a very unique kind of hydrothermal vent called an alkaline vent" – cut to shot of white tower like structure underwater - "and about 4 billion years ago when life on earth began, sea water would have been mildly acidic," – cut back to Cox – "so here is that proton gradient, that source of energy for life, you've got a reservoir of protons in the acidic sea water and a deficit of protons around the vents – "cut to underwater shot of vent, lit up by submarine light but surrounded by total darkness, fade to different vent "And the vents don't just provide an energy source, they're also rich in the raw materials life needs" – shot of underwater cliff face with strange effect occurring in water where vent is releasing gas – "; hydrogen gas, carbon dioxide and minerals containing iron, nickel and sulphur." – soundtrack becomes more prominent, uplifting orchestral music – "But there's more than that, see these vents are porous" – cut back to Cox – "there are little chambers inside them, and they can act to concentrate the organic molecules," – cut to shot of submarine filming vents, taken from another submarine, lighting up small patch of vent in darkness, shot of submarine arm removing chunk of rock from vent - "you've got everything inside these vents, you've got concentrated building blocks of life" – close up of sub arm holding chunk of rock - "trapped inside the rock and you've got that proton gradient" –cut back to Cox - "you've got that waterfall that provide the energy for life, so this could be where your distant ancestors come from places like these could be the places where life on earth began"

25:21-26:20: cgi shot of something glowing and pulsing "the first living things might have started out as part of the rock that created them" – cgi shot of crack in rock which focuses in on something which resembles a cell, sepia tones to suggest age - , "simple organisms" – cut to cgi shot of grey spheres with what look like chromosomes on their surface suspended in a substance - "that exploited energy form the naturally occurring proton gradients in the vents." – cut to shot of 1000's of butterflies in trees – "And we think this because living things still get their energy using" – cut to close up of butterfly on flower, graphic label appears, reads 'Monarch Butterfly/Mexico – "proton gradients today." – cut to shot of kangaroos boxing in a misty dawn, shot of a tree from below looking up, with graphic label which reads 'Mountain Ash/Australia' , cut to close up of toad, with label, reads 'Fowler's Toad/U.S.A', cut to close up of lions eyes blinking, cut to Brian Cox climbing off boat as the sun sets behind him, voiceover begins - "deep within ourselves the chemistry the first life exploited in the vents is wrapped up" – shot of man fishing on raft, same one as used previously - "in structures called mitochondria" – wider shot of man on raft as the last light fades from the sky, label appears attached to him, reads 'Homo Sapiens/Philippines' - "microscopic batteries that power the processes of life."

26:21 –27:39: close up of Cox undoing an envelope, wider shot of him removing things from envelope, begins – "This" – holds up picture to camera" – "is a picture of the mitochondria" – close up on picture – "from a little brown bat, this is a picture of the mitochondria from a plant" – shows different picture – "it's actually a member of the mustard family" – close up on different picture – "this is a picture of the mitochondria in bread mould" – reveals another picture – "and this the mitochondria inside a malaria parasite" – shots of pictures on table next to each other – "so the fascinating" – cut back to Cox sitting on table - "thing is that all these animals and plants and in fact virtually every living thing on the planet uses proton gradients" – cut back to pictures - "to produce energy to live. Why?" – cut back to Cox – "Well the answer is probably because all these radically different forms of life" – cut back to the pictures - "share a common ancestor, and that common ancestor was something that lived in those ancient" – cut back to Cox - "undersea vents 4 billion years ago where naturally occurring" – close up on Cox's face - "proton gradients provided the energy for the first life, so if you're looking for a universal" ¬– shot of insect crawling across pictures - "spark of life then this is it," – cut back to Cox - "the spark of life is proton gradients."

27:40-28:53: cgi shot of the earth from space, guitar music begins, helicopter shot of tropical archipelago of small lush islands, voiceover begins - "in those 4 billion years that spark has grown into a flame" – cut to shot of Brian Cox on speedboat, looking past camera –"and a few simple organisms clustered around a hydrothermal vent have evolved" – shot of rocky island from boat – "to produce all the magnificent diversity that covers the earth today." – moved from probably to definitely occurred – quickly become a narrative that is set in stone – shot of Cox walking through forest, shot of lake which a fish jumps out of, wider shot of lake surrounded by tree's which overhang it and birds circling it, underwater shot of seaweed swaying in current, underwater shot of boat moving past overhead, cut to Cox paddling canoe, delivers piece to camera – "today life on earth is so diverse, it covers so much of the planet that you can find places like this lake, its effectively its own sealed eco-system, its salt water its connected to the sea but, but its only connected through small channels through the rock so that means that the marine life in here is effectively isolated"

28:54 – 30:30: shot of lake surface with swirling sediments floating on surface, wider shot of Cox paddling across lake, shot dominated by large bank of tress beyond him, close up of Cox in canoe looking out and into the lake, shot of lake surface, beneath which can be made out a small jellyfish, voiceover begins – "this is the golden jellyfish" – cut to close shot of jellyfish with graphic label, reads 'Golden Jellyfish/Mastigias papua etpis - "it's a unique sub-species, only found in this one lake, on this one island in the tiny Micronesian republic" – cut to underwater shot of shafts of sunlight penetrating to the lake bottom – "of Palau" – one jellyfish comes into view in sunlight – "they used to live like most jellyfish" – extreme close up of top part of jelly fish from underneath – "cruising the open ocean catching tiny creature, zooplankton, in their long tentacles," - pull back to less extreme close up of jellyfish spinning slowly – "but today their tentacles have all but disappeared because the golden jellyfish" – close up on stubs of tentacles – "have evolved to do something that very few other animals can do" – cut to shot of Brian Cox in wet suit and snorkel falling of canoe into lake, underwater shot of him landing in lake, shot from under him with a number of jellyfish between him and the camera, close up of his face in goggles and with snorkel in under water, swimming through an increasing number of jellyfish, with many more behind him, shot of him surfacing, delivers piece to camera whilst in water – "It really is incredible, there are, I want to say millions of jellyfish, oh as far as you can see, all the way down til the, til the light vanishes there are jellyfish and you can see them congregating in the sun, if you go over there to where the lakes in shade there are just none, and in this pool of light beneath the sun there are millions of them, beautifully elegant things just floating there, ha-ha, I'm not being unduly hyperbolic its quite remarkable " – puts his head back underwater and makes noise of surprise

30:37 – 31:49: underwater shot of Cox snorkelling looking at jellyfish, camera follows a jellyfish as it swims downwards and reveals many more below, choral music, peaceful and ethereal, shot of Cox floating at surface looking at a jellyfish next to his face, shot of hundreds of jellyfish, voiceover begins – "this lake is home to over 20 million jellyfish" – cut to shot looking up at sun with jellyfish in between (used in opening credits) – "who's success comes down to a remarkable adaptation, their bodies play host to thousands of other" – close up of one jellyfish from underneath, sun behind it, making rainbow through water –"organisms, photosynthetic algae that harvest energy directly from sunlight" – cut back to shot of lots of jellyfish from above, cut to wider shot of even more jellyfish, cut to extreme close up (possibly cgi) – "the jellyfish engulf the algae as juveniles, and by adulthood" – even more extreme close up of algae cells inside jellyfish – "algal cells make up about ten percent of their biomass" – cgi even more extreme close up of a few algal cells, bright light behind them – "grouped into clusters of up to 200 individuals they live inside the jelly fishes own cells" – less extreme close up of jellyfish body

31:50 - 32:48: underwater shot of lots of jellyfish quite close up, fills the screen –"the golden jellyfish uses algae to get most of its energy" – shot from below of jellyfish completely blocking view to the surface, small amount of sunlight filtering through, choral music more prominent – "from photosynthesis" – cut to slightly wider shot but same as before with jellyfish blocking sun, shot of Cox snorkelling from below with jellyfish blocking his face, cut to him floating in water delivers piece to camera – "now the ones at the surface, wow there's one right there, they're gently turning, the reason that they do that is to give all their algae am equal dose of sunlight" – cut to shot of one jellyfish underwater, slowly rotating – "so they're quite democratic creatures, just making sure they get as much food as they can" – cut back to floating Cox – "they just come up to you and" – makes hand gesture wiggling his fingers –

"jellying around, photosynthesising" – cut to shot of jellyfish from below, sunlight glowing through it , cut back to floating Cox – "they tell me they don't sting, but I'm sure I've got a tingling finger"

32:49 – 34:12: underwater shots of jellyfish with boat gliding above, voiceover - "and it's not just their anatomy that's adapted to harvest solar energy. Every morning as the sun rises the jellyfish begin to swim towards the east" – time-lapse shot of sun moving over lake, cut to Cox in boat on lake – "now as the sun tracks across the sky they move back again towards the west where they spend their nights" – cut to shot of lots of jellyfish underwater, cut back to Cox in boat – "so the jellyfish have this beautiful, intimate and complex relationship with the position of the sun in the sky" – cgi close up of jellyfish, cgi zoom into algae cells, voiceover – "as sunlight is captured by their algae, its converted into chemical energy, energy they use to combine simple" – graphic labels reading H2O and CO2 appear overlaid on algae cells "molecules, water and carbon dioxide" - graphics combine and form a ring chemical structure of variously bonded H C and O's – "to form a far more complex one, glucose" – more glucose ring graphics appear – "once absorbed by the jellyfish glucose and other molecules not only power their" – fade to shot of lots of jellyfish underwater, glucose graphics remain – "daily voyage across the lake, they provide the basic building blocks jellyfish use to grow the elegant" – shot of single jellyfish – "and complex structures of their bodies"

34:12 – 35:04: cut to shot of Cox walking down a beach towards the camera - "so the jellyfish" - close up of Cox walking, delivers piece to camera, sea in background with sun setting behind him – "through their symbiotic relationship with the algae absorb the light the energy from the sun and they well to live to power their processes of life and that's true directly or indirectly for every form of life on the surface of our planet. But things are a little bit more interesting than that because energy is neither created nor destroyed so life doesn't eat it somehow, it doesn't use it up, it doesn't remove it from the universe, so what does it do?" – cut to shot of small waves breaking on shore, twilight, voiceover – "To understand how energy sustains life you have to understand exactly what happens to it" – cut to shot of Cox walking down beach, silhouetted against late evening sky - "as the cosmos evolves."

35:05 – 36:07: cut to cgi of pulsing glowing multi-coloured mesh , then cgi flash/explosion, rapidly expanding blue glowing ball, becomes glowing and pulsing purple cloud, voiceover begins – "in the first instance after the big bang, there was nothing in the universe but energy" – cut to shot of similar looking cloud now circular and bluer, flashes changes to purple less circular, waves moving through it, another explosion – "as it changed from one form to another" –white sphere forms with flaming lines extending from it, pull back to reveal smaller black spheres – "galaxies, stars and planets were born" – flames become more nebulous and cloud like, with flashes of light in them, another explosion this one resembling the sun- "but while the total amount of energy in the universe" –cut to something which resembles a galaxy – "stays constant" – then a planet forming from dust cloud - "with every single transformation" – zoom to see pinprick of light moving rapidly in a circle – "something does change" – pan right to see flaming ball – "the energy itself becomes less and less useful, it becomes ever more disordered" – wall of flame rises up from bottom of screen and destroys flaming ball, white out, then cut back to beach, with Brian Cox squatting on it looking out to sea – "and you can see this process in action" – cut to shot of sea, label appears reads 'Energy from the sun/3200000000000000000000000000000 joules/day' - "as energy from the sun hits the surface of the earth."

36:08 – 37:21: cut to shot of Cox squatting on beach, delivers piece to camera – "now think about this sand on the beach its been under the glare of the sun all day, it's been absorbing its light which has been heating it up and now that the sun is dipping below the horizon and the sand is still hot to the touch because its reradiating all the energy that it absorbed as heat back into the universe, and the key word there is all, all the energy, see if it didn't do that it would gradually heat up day after day after day and eventually I suppose the whole beach would melt" – close up on Cox's face – "so what's changed? Well it's the quality of the energy if you like, I mean think about it, if as much energy is coming back off this sand now as it absorbed from the sun, then it should be giving me a sun tan, right I should need sun cream if I sit looking at this beach all night and obviously I don't. The difference is that this energy is of a lower quality, it can do less, its heat, which is a very low quality of energy indeed. So what the sands done is take highly ordered high quality energy from the sun and convert it to an equal amount of low quality, disordered energy" – cut to shot of sea, waves breaking on it

37:28–38:15: "this descent into disorder" – cut to shot of Cox's face in profile looking out to sea - "is happening across the entire universe". – cut to shot of sea with sun setting, cut to cgi of nebulous clouds and stars in space, voiceover - "As time passes ever single joule of energy is converted into heat. The universe gradually cools towards absolute zero" – things in cgi space begin to fade and stars go out - "until with no ordered energy left the cosmos grinds to a halt and every structure in it decays away" – fade to completely black screen

38:15-39:17: cut to Cox walking through jungle, voiceover – "yet whilst the universe is dying everywhere you look –"cut to close up of millipede walking over a leaf – "life goes on. It's a deep paradox that Schrodinger" – cut to Cox sitting in jungle, takes book out of bag, label appears, reads 'What is Life? /Erwin Schrodinger – "was well aware of when he wrote his book in 1943. 'how can it be' writes Schrodinger" –cut to Cox sitting amongst leaves, reading from book to camera – "'that the living organism avoids decay' in other words how can it be that life seems to continue to build increasingly complex structures when the rest of the universe is falling to bits, is decaying away. Now that's a paradox because the universe is falling to bits it is tending towards disorder, that is enshrined in a law of physics called the second law of thermodynamics and I think that most physicists believe that it's the one law of physics that will never be broken." E-OC

39:17-40:10: shots of small leafy plants near forest floor, Brian Cox out of focus behind them, cut to thermal imaging shot of cats, then a family group, voiceover starts "the key to understanding how life" - thermal shot of chicken – "obeys the laws of thermodynamics is to look at both the energy it takes in" – thermal shot of cats again - "and the energy it gives out" – shot of chicken, then cut to close up of Cox holding thermal camera, delivers piece to camera – "this is a thermal camera so hot things show up as red and cold things show up as blue" – close up of thermal camera viewing screen, cut back to Cox holding camera – "so what you're seeing here is that the chicken is hotter than its surroundings. Now heat is a highly disordered form of energy so the chicken is radiating disorder out into the wider universe – cut to shot of chicken through thermal camera

40:11-40:59: shots of woman scattering seeds outside her house with family behind her, voiceover - "By converting chemical energy into heat" – shot of man sitting at table – "life transforms energy from an ordered" – shot of Cox filming a child with thermal cam – "to a disordered form" – thermal image of child -"in exactly the same way as every other process in the universe." – thermal image of chicken graphic label reads 'Chicken/10.45 joules/second', thermal image of chicken, label reads Chick/3.1447 joules/second' - "In fact every single" – thermal image of baby, label reads 'Baby/39.12 Joules/second' – " human being generates six thousand times more heat" – thermal shot of family - "per kilogram than the sun" – life is both unified with other universal processes yet also superior to them, humans are more powerful than the sun – comforting/uplifting account – cut to shot of Cox filming things with thermal camera – "and its by converting so much energy" – thermal shot of kitten with label reads 'Kitten/3.33 joules/second' – "from one form to another that life is able to hang on to a tiny amount of order" – cut to shot of children – "for itself, just enough to resist the inevitable decay" – shot of cat and chicken – "of the universe"

41:00-42:21: thermal shot of Cox with label 'Professor of Physics/82.4 joules/second', begins piece to camera "so it's no accident that living things are hot, they export heat to their surroundings because it's an essential part of being alive" – cut to normal close up of Cox – "Living things borrow order from the wider universe and then they export it again as disorder, buts it not precisely imbalance they have to export more disorder than the amount of order they import, that is the content of the second law of thermodynamics, and living things have to obey the second law because they're physical structures they obey the laws of physics" – cut to cgi of pulsing glowing cloud, voiceover "Just by being alive we too are part of the process of energy transformation that drives" – slow cgi stellar explosion - "the evolution of the universe." – pulsing purple cloud followed by another explosion - "We take sunlight, which has its origins at the very start" – reuse of shots from before, flaming ball with black spheres, exploding sun-like star - "of time and" – galaxy formation shot, followed by sun like star – " transform it into heat, that will last for eternity." – close up of sun – "So far from being a paradox" – solar system formation very quickly shot - "living things can be explained by the laws of physics" – familiar cgi shot of solar system with sun peaking around the earth and the moon on the other side - "the very same laws which describe the falling of the rain" – cut to Brian Cox walking through sun dappled forest - "and the shining of the stars" – choral music with lots of vibrato, gives ethereal supernatural, alien feel

42:23 – 43:22: shot of Cox in profile in forest, then shot of him in ¾ profile looking out past camera, slow-motion shot of dragonfly landing on branch, close up of dragonfly landing, close up of dragonfly head, voiceover – "the dragonfly draws its energy from proton gradients" – cgi of grey spheres – "the fundamental chemistry" – cut to close up of dragon fly on branch – "that powers life" – close up of dragonfly wings, then tail- "but the real miracles are the structures they build with that energy" – shot of dragonfly taking off – "borrowing order to generate cells" – shot of dragonfly hovering – "arranging those cells into tissues" – close up of dragonfly wing, then body – "and those tissues into the intricate architecture" – close up of dragonfly eye – "of their bodies"

43:23 – 44:34: Cox delivers piece to camera in front of pond from beginning of programme - " so we've developed a quite detailed understanding of the underlying machinery that powers these dragonflies and indeed all life on earth and whilst we don't have all the answers it is certainly safe to say that there is no mysticism required, you don't need some kind of magical flame to animate these little machines they operate according to the laws of physics and I think they're no less magical for that." – choral music begins, pan down from canopy of trees, voiceover – "yet the dragonfly will only maintain this delicate balancing act" – shot of dead dragonfly in water, same as used earlier – "for so long, because all living things share the same fate" – shot of a tree, label appears reads 'Tree/<4884',Cox walks past tree label appears, reads' Human/ <122 years' – "each individual will die, but life itself endures" – Shot of Cox in profile looking out of camera, shot of dragonflies over pond – "This is because there is something" – close up of dragonfly landing on branch" - "which separates life from every other process in the universe…"

44:35 – 45:29: moving shot of forest canopy from below, shot of Cox in boat taken from boat behind, close shot of Cox on boat looking into jungle, elephant noise echoes through forest, shot of monkey in tree, shot of boat travelling up narrow jungle river, voiceover – "this is the Malaysian state of Saba, on the northern tip of the island of Borneo" – shot of Cox riding in front of boat looking out into jungle -"it's one of the most bio-diverse places on the planet" – shot of stalk/heron on tree branch, close up of Cox's face in ¾ profile looking out beyond the camera – "its home to 15 thousand plant species" – shot of worm/leech climbing up leaf – "3000 species of tree" – shot of monkey swinging in branches – "420 species of bird" – shot of Cox looking at tree with monkeys in it, bird flies past, used near the beginning of programme – "and 222 species of mammals" – brief shot of close up of Cox disappears into halo of lens flare, then cut to him sitting in boat in front of a couple of elephants –

“including those” – turns and points at the elephants, followed by trumpeting elephant sound

45:30-46:17: cut to shot rising above canopy, voiceover – “Borneo’s rainforests contain trees that are though to live for more than a thousand years” – cut to shot moving through misty canopy, sun behind clouds – “but the forest itself has existed for tens of millions of years” – cut to shot of shafts of sunlight through leaves and branches, cut to shot large insect in leaf mulch “the reason it persists is because each generation of animal, plant passes the information to recreate itself” – cut to shot of spider - “on to the next generation and that’s possible because of a molecule found in every cell” – cut to shot of snake sliding over branch- “of every living thing, a molecule called DNA”

46:18 – 48:17: shot of Brian Cox walking upstairs onto a wooden balcony, jungle behind him, camera positioned on balcony floor, cut to shot of Cox in open, wooden bar room, sits at bar, next to him is bottle of vodka, fairy liquid, test tube, delivers piece to camera – “now all I need to isolate my DNA is some washing up liquid, a bit of salt” – picks up salt sachet from behind vodka bottle – “and then chemist’s best friend, vodka” – close up on Cox’s face – “now to get a sample of DNA I can just use myself, if I just swirl my tongue around on the edge of my cheek, I’ll dislodge some cheek cells into my saliva” – does that, cuts back to bar shot, shows Cox spit into test-tube, misses – “(laughs) I missed the test-tube, there we are, a physicist, doing an experiment” – tries again this time gets spit in test tube, cuts to closer shot – “there, I add a bit of washing up liquid” – pours washing up liquid into tube – “now what this will do, is it will break open those cheek cells, and it will also degrade the membrane that surrounds the cell nucleus, that contains the DNA” – Cox shakes test-tube as he’s holding it up to camera – “salt will encourage the molecules to clump together” – empties sachet of salt into tube – “DNA is insoluble in alcohol, so we should get a layer of alcohol” – adds a few drops of vodka to the tube – “ with the DNA molecules precipitated out” – close up of test tube with Cox face looking intently at it in background, contents of tube separated into three layers, foam on top with clear layer then white sediment at bottom –"yeah, there can you see those strands of white" – close up of bottom of test tube white strands now in clear layer - "so in that cloudy, almost innocuous looking solid, are all the" – cut back to Cox holding test tube up to his face – "instructions needed to build a human being" – cut back to close up of test tube, cut back to Cox face – "so that is what makes life unique

48:18-49:21: lingering shot of Cox staring at test-tube with DNA in, cut to shot of Cox feet walking up muddy jungle path, out of focus shot of Cox through leaves of plant, shot of Cox walking up path towards camera, voice over "only living things have the ability to" – cut to shot of big grasshopper on leaf - "encode and transmit information in this way" – shot of Cox walking up path out of focus, leaves in foreground, shot mushrooms attached to branch – "and the consequences of that profoundly" – shot of Cox walking through jungle undergrowth away from camera - "effect our understanding of what it is to be alive" – shot of butterfly taking flight form leaf, cut to Cox on path, turns and delivers piece to camera – "this rainforest is part of the Sepilok forest reserve and, in here somewhere, are some of our closest genetic relatives" cut to shot of fern from underneath with trees above it and sky beyond, circling shot of Cox from below, looking out into jungle, canopy of trees above him, shot of something moving through undergrowth, blurred shot of movement through leaves, shot of Cox smiling at something off camera – "shh" – shot of hairy orange mass though leaves, another blurred shot of orange movement in leaves, shot of Cox pointing into trees, turns to camera – "there, there, can you see?" - shot focuses on orang-utan in tree, cut to much closer shot of orang-utan in tree, with label which reads 'Bornean Orang-utan/Pongo Pygmaeus'

49:21 – 50:16: shot of older orang-utan in tree, voiceover begins – "orangutans are highly specialised for a life lived in the forest canopy" – shots of orang-utan swinging through branches – "their arms are twice as long as their legs" – different shot of orangutan in tree – "and all four limbs are incredibly flexible" – shot of Cox watching the trees from low down looking up, cut to shot of orang-utan in branches – "each one ending in a hand" – shot of orang-utan picking at its foot/lower hand with its two upper hands, concentrating, performing vaguely human like action – "who's curved bones are perfectly adapted" – shot of orangutans hands round a branch, climbing down it – "for gripping branches" – shot of young orang-utan hanging upside down, smiling, shot of Cox looking into tree's, - "these adaptations" – shot of orangutans hand dangling – " are encoded in information passed down in their DNA" – shot of young orangutan chewing on something, shot of Cox watching an orang-utan in a tree, back of Cox's head out of focus in foreground, turns to camera smiling – "(laughs), he's got a hat on" – close up of orang-utan with leaf on his head – "he has actually just put a hat on" – sound of bag being unzipped, shot of Cox bending down to take something out of it, stands up with iPad, shot of orang-utan in nest, shot of orang-utan leaning on branch, another vaguely human pose,

50:18 – 51:49: shot of Cox with iPad under tree with orang-utan just above him, flipping through pages on iPad, delivers piece to camera – "this is the orangutans genetic code, it was published in 2011 and there are over three billion letters in it" – close up on iPad screen, cut back to Cox below tree – "if I flip through it" – flips through it quickly – "look at that" –close up of screen, see letters ACGT in various order – "now its composed of only four letters a c t and g, which are known as bases" – close up of Cox's face – "they're chemical compounds, they're molecules, and the way it works is beautifully simple, they're grouped into threes, called codons" – close up of iPad screen – "and some of them just tell the code reader if you like, how to start or where to start and when in its gonna stop" – cut to shot of Cox, tree and orang-utan above him, orangutans shakes tree branches, and another runs up tree to, Cox laughs, turns to camera – "she's fast" laughs again – cut to shot of older orangutan staring intently, cut back to Cox, tree orang-utan – "so you'd have a start and a stop, in between each group of three codes for a particular amino acid" – shot of orangutan hanging from tree branch, cut back to Cox's face – "now amino acids are the building blocks of proteins, which are the building blocks of all living things" – cut back to Cox, tree orang-utan shot – "so you would just read along and find a start stop and then you would go along in threes; build amino acid build amino acid build amino acid, stitch those together into a protein and if you keep doing that, eventually you'll come out with one of those" – points at orangutan in tree

51:49 – 52:54: shot of orang-utan in tree, label appears with genetic code letters, voiceover begins – "well it's not that simple of course, but the basics are there" – close up of code on iPad screen – "this code written in there are instructions" – cut to Cox tree orang-utan shot, Cox points at orang-utan – "to make him", turns to smile at camera, cut to close up of orangutans body, hands and arms, shot of Cox with camera in his hand, shot from below, lens flare haloing him slight, looking beyond camera, voiceover –"to faithfully reproduce those instructions" – cut to shot of orangutan in tree – "generation after generation, the orangutans and indeed all life on earth, rely on a remarkable property of DNA" – cut to out of focus shot of orang-utan in background, with three in sharp focus in foreground which an ant runs down – "its incredible stability and resistance" – orang-utan brought into focus - "to change." – cut to Cox with jungle in background, delivers piece to camera – "every time a cell divides its DNA must be copied and the genetic code is highly resistant to copying errors, the little enzymes, the chemical machines that do the copying on average make only one mistake in a billion letters, I mean that's like copying out the bible about 280 times and making just one mistake

52:53 – 54:20: shot of orang-utan in tree, voiceover – "that fidelity means adaptations are faithfully" – cut to different orangutan in different trees – "transmitted from parent to offspring. And so while we think of evolution as a process of constant change" –shot of orang-utan climbing down tree – "in fact the vast majority of the code" – shot of older looking orang-utan sitting in tree – "is preserved" – shot of orang-utan swinging in branches – "so even though we're separated from the orangutans by nearly 14 million years of evolution, what's really striking is just how similar we are" – shot of orangutans arms clinging onto branch, close up of orangutans face, music begins, piano – "and those similarities are far more than skin deep" – cut to Cox below tree with orangutan in, delivers piece to camera – "orangutans are surely one of the most human of animals, and they share" – close up of top half of orangutans body and head – "many behavioural traits that you would define as being uniquely human" – shot of baby orang-utan, voiceover – "they nurture their young for eight years before they let them go on their own into the forest, in that time" – shot of orang-utan climbing along branch – "the infants learn which fruits are safe to eat and which are poisonous" – shot of young orang-utan chewing on branch – "which branches will hold their weight and which won't. And they can do all that because they have memory, they can" cut back to Cox in front of tree, delivers to camera – "remember things that happened to them in their life and learn from them and they can pass them on from generation to generation" – Cox watches orang-utan jump out of tree and scamper off

54:21 – 56:12: shot of lizard on a tree trunk, voiceover – "and that deep connection extends far beyond our closest relatives" – close up of insects head and eyes – "because our DNA contains the finger print" – shot of beetle on leaf – "of almost four billion years of evolution" – shot of laves and canopy, bird noises in jungle, cut to Cox sitting in jungle clearing with pen and pad, delivers piece to camera – "if I draw a tree of life for the primates then we share a common ancestor with chimps" – begins drawing tree of life – "and bonobos about four to six million years ago. And if you compare our genetic sequences you find that our genes are 99% the same. You go back to the split with gorillas" – close up on tree of life being drawn – "about 6 to 8 million years ago, and you get, if you compare out genes, and you find that they are 98.4% the same" – writes this on tree of life – "back in time again, common ancestor with our friends over there the orang-utans, then our genes are 97.4% the same," – cut back to Cox – "and you can carry on, all the way back in time, you can look for our common ancestor with a chicken and you'd find that our codes are about 60% the same and in fact, if you look for any animal, like him, that little fly" – points to fly with his pen – "or a bacteria, something that seems superficially completely unrelated to us then you will still find sequences in the genetic code which are identical to sequences in my cells. So this tells us" – pull back to slightly wider shot – "that all life on earth is related, it's all connected through our genetic code"

56:13-57:20: shot through foliage of Cox standing up +walking away, fade to black then a cgi double helix made from words 'deoxyribonucleic acid' appears, voiceover, choral music begins - "DNA is the blueprint for life but its extraordinary fidelity means that it also contains"- cut to shot of lemur in tree – "a story, and what a story it is." – cut to shot of red crab on branch - "The entire history" – shot from above of hundreds of wildebeest – "of evolution from the present day all the way back" – cgi shot a tree of life, moving back from human towards a start point – "to the very first spark of life and it tells"- cgi of grey spheres, used before when discussing first life on earth – "us that we're connected not only to every plant and animal" – shot of thermal vents from earlier, ethereal choral music building in volume and prominence, crescendos - " alive today but to every single thing that has ever lived" - shot of sepia first cell used earlier, music now becoming euphoric synth orchestra style sound, shot of forest canopy looking vertically up from below, close up of small orange fly on mossy log, close up of aquatic creatures eye, close up of tiny mushrooms, cut to Brian Cox walking along a river bank, camera following close behind, music now loud and euphoric, shot of Cox looking out over rive, cut to Cox standing on a pontoon, shot form far away up the river, Cox sits on the pontoon creation story/positive force

57:21-58:31: Cox sitting on pontoon on river, stormy evening sky above him ,music becomes more subdued, fades out, delivers piece to camera "the question what is life is surely one of the grandest of questions and we've learnt that life isn't really a thing, at all, it's a collection of chemical processes that can harness a flow of energy, to create local islands of order like me and this forest, by borrowing order from the wider universe and then transmitting it from generation to generation through the elegant chemistry of DNA. And the origins of that chemistry can be traced back 4 billion years most likely to vents in Primordial Ocean. And most wonderfully of all the echoes of that history stretching back for a third of the age of the universe can be seen in every cell of everything on earth." Close up of Cox's face – "And that leads to what I think is the most exciting idea of all, because far from being some chance event ignited by a mystical spark the emergence of life on earth might have been an inevitable consequence of the laws of physics. And if that's true then a living cosmos might be the only way our cosmos can be." – cut to cgi shot of earth from underneath, sun lighting up a small amount of blue sea, jungle noise begins, then music; Eric Idle new version of the galaxy song from the meaning of life (Monty python), cut to cgi shot of earth and moon in front of sun, wider shot of same with earth as a small speck on the sun, credits roll, shot of galaxy as perspective moves further and further away, shot of bright centre of galaxy

Episode Ends

Wonder of Life Episode 3 Transcript

00:00 – 01:00: shot of warehouse building in middle distance surrounded by exotic greenery, pan down to reveal Brian Cox walking toward camera up a train track next to rusted out carriage, plucked guitar music, shot of women and two young children looking out of upstairs window of wooden house/hut, shot of Cox in middle distance walking towards town, other people walking around him, church prominent in centre of town, graphic label appears, 'Andasibe, Eastern Madagascar', shot of spiders web, fills screen with spider in centre, Cox voiceover – "In 2009 a new species of spider was identified" – focus shifts to other spider webs behind first one, then extreme close up of spider, pan along body to head – "a spider with super powers" – close up of jaws and fangs, then of whole head, shot of Cox walking up rural road toward camera – "it was named exactly 150 years after the publication of Darwin's On the Origin of Species, in which" – cut to closer shot of Cox walking next to camera, piece to it – "he explained why life on earth is so diverse and so complex" – close up of geckos foot, then of its head

01:01 – 01:59: close shot of tree trunk with path beyond, Cox walks into shot going away from camera, voiceover begins – "Darwin's theory of evolution by natural selection was built on the work of naturalists" – shot of hairy caterpillar on branch – "who were discovering thousands of new species" – shot of Cox walking through undergrowth, camera placed in foliage, Cox walks past it – "across the world" – shot of lemur in tree eating leaf, close up of lizard/frogs eye, blinking, then close up of frogs face – "that process of finding species new to science and naming them continues to this day" – cut to Cox walking through jungle, piece to camera – "and its recognised in the name of this newly" – stops by body of water – "discovered arachnid" – close up of spider on web wrapping insect in silk – "Darwin's Bark Spider" – label appears, reads 'Darwin's Bark Spider/*Caerostris darwini*' – "the spider occupies a unique niche it can hunt" – shot of large web over river caught in evening sunlight – "where no other spider can" – pan down to reveal different web in sunlight – "that spider creates the largest webs" – cut to Cox on river bank, piece to camera – "found anywhere on earth and in order to do that it has to produce the strongest silk of any spider, they can span over 25 metres"- Cox sweeps arm between to tree's in distance and graphic line appears between them with label reading '25.2 metres' – "across lakes and rivers and actually no one knows how they get there webs across such a large distance"

02:00 – 02:59: close shot of line of spider silk across water, then large web brought into focus, shot of jungle and trees from low down looking up towards canopy, men approach camera though undergrowth, voiceover – "but Darwin's bark spider is just one of thousands of unique species of animals and plants" – closer shot of group of men walking through jungle, - "that you find in Madagascar" – shot of group of men all black except one white man, carrying backpack, investigating something on floor,- "the rainforests here" – shot of one of the men picking up large round object, possibly seed pod – "are one of the most biodiverse places" – shot of Cox setting up camera in light box with some carefully placed leaf matter – “on the planet” – close up of shot of large green insect being placed in box on leaf matter, label reads ‘Green Emerald Giant Pil Millipede/*Zoosphaerium neptunus*’ , shot of man walking through jungle, mostly obscured by undergrowth – “and each year more” – shot of lizard in gloved hand, label reads ‘Graceful Madagascar Ground Gecko/*Paroedura gracilis’* – “discoveries are made as researchers” – shot of chameleon climbing onto branch from hand, label ‘Parson’s Chameleon/*Calumma Parsonii’* – “try to understand why this tiny corner” – shots of men placing sticks and leafs matter on mat on balcony – “of the universe is so prolific” – shot of Cox adding to mat contents, then begins – “all of these living things were found within” – shot of Cox on veranda of house in jungle, sitting behind mat – “a five minute walk of this field station” – close up of mantis on leaf, label ‘Madagascan Marbled Mantis/*Polyspilota aeruginosa’* – and the diversity is remarkable” – close up of turtle’s head, label ‘East African Black Mud Turtle/*Pelusios subniger’* - “there’s a chameleon there” – Close up of chameleon, label ‘Brown Leaf Chameleon/*Brookesia Superciliaris’* – “these are orchids” – cut back to close shot of Cox behind mat of vegetation pointing out various things – “this big green leaf is a travellers palm, there are four species of mushroom” – close up of mushroom, label ‘Parchment Fungus/*Stereum sp.’* – “on that branch alone” – shot of different mushroom, label ‘Velvet Parachute/*Marasmius elegans’*

03:00 – 04:02: close up of fungus,, label ‘*Corolopsis polyzona’* ,close up of rodent, label ‘Fossorial Tenrec/*Oryzarites hova’*, Cox begins – “across Madagascar there are over 14000” – shot of ant on fruit on tree, label on fruit ‘*Rubiacceae’* – “species of plants there are hundreds of species” – cut back to Cox behind mat -“ of mammals and birds and reptiles and over 90% of them are unique to this island” – cut to helicopter shot flying over rainforest canopy, shots of trees from helicopter, orchestral uplifting themes music is prominent, cut to shot of Cox picking well camouflaged gecko from tree, cut to close up of gecko – “how could it be that so many diverse living things, so beautifully” – cut back to Cox behind mat –“adapted to their environment could emerge form a universe that is governed by a simple set of natural laws" – close shot of contents of mat –"the fact that we know the answer to that question is one of the greatest achievements in science and in this film I want to explore how these endless forms most beautiful have emerged from a lifeless cosmos"

04:02- 04:15: opening credit sequence – same as in episode 1

04:16- 05:13: close up shot of long grass stem, words fade onto screen, 'endless forms most beautiful', music African singing, slow with gentle percussion, shot of giraffe walking through grassland with small trees, shot of zebra and small deer like animal, zebra looks at camera, shot of rhino facing camera, shot from car of savannah, sun low on horizon, see front of car, label appears as if fixed in landscape, 'The Kruger National Park, South Africa', car drives past it, shot of Cox's refection in wing mirror of jeep as it drives through park, voiceover – "Africa, a whole continent full of creatures utterly different" – shot of zebra from moving car – "from those in Madagascar" – shot of jeep with Cox in through bushy tree's – "but the diversity of life doesn't stop at what you see" – shot of rhino appearing from behind bush –"because within each individual" – shot of zebra's –"lies another hidden world of complexity"

05:14 – 06:26: slow motion shot of Cox walking up path toward camera, two small lions behind him, shot of Cox's legs with lions playing on path behind him as he continues to walk, shot through grass of lion running up path, shot of two lion cubs play fighting, shot of Cox sitting on log with lion running up to him between his legs, Cox grabs lion and starts stroking it, shot of Cox in front of log with lion, label attached to it ' Hand-reared lion/*Panthera leo'* cut back to shot of Cox on log stroking lion, piece to camera – "this believe it or not is the top predator in Africa, or she will be when she's older, she's only about 8 weeks old now" – close up of Cox playing with lion on her back, voiceover –"her body is built from a host of different molecules" – close up on lions mouth and teeth –"and by far the most diverse group are known as proteins" – cut back to Cox playing with lion by log, piece to camera – "you can see the proteins here, those claws" – close up on claws, have graphic of molecule attached to them – "so vital to the lions survival are made of a protein called keratin" – cut back to Cox and lion – "her eyes also absolutely vital" – cut to close up of lion blinking (same shot as used in opening credits sequence) – "to her survival, have a protein" – graphic molecule label appears next to eye – "called opsin, which is bound to a pigment" – cut back to Cox and lion – "to make structures called ridopsins which allow her to see in colour and also allow her to see very well at night when she's hunting " – lion runs off

06:26 – 07:35: shot of lion running towards camera in slow-mo., Cox continues –"there are also proteins in her muscles" – cut back to Cox by log, lion runs past and he tries to grab her, cut back to shot of lion running towards camera with molecule graphic next to her shoulder – "miacin and actin which are the things that allow her to run away" – cut back to Cox by log with lion, cut to shot of lion looking at something intently, molecule graphic next to its face – "the proteins in a lion come in countless different forms" – lion walks towards camera until the molecule graphic is in middle of screen, lion goes out of focus leaving just molecule – "but they all share something in common, a backbone of carbon" – C's in molecule graphic light up – "an atom that's able to form long complex" – molecule rotates slightly to reveal it all – "molecules. Of all the 92 elements there really is" – cut back to Cox in front of log, piece to camera – "only one that has that appetite for bonding, its four electrons, to share them with other molecules, carbon will share those electrons with nitrogen with oxygen with hydrogen and critically with other carbons to build up these immensely complex chains, the amino acids and the proteins which are the building blocks of life

07:35 – 08:51: shot of lion cub snarling, Cox continues – "so to understand our planets endless diversity we must begin by considering this life giving element" – shot of Cox playing with lion, says to it – "I've got a few scratches now because of you, because of your proteins" – shot of lion being offered bit of wood to chew – "after all to build a lion you must first build carbon" – shot of Cox in front of log with lion – "and that's a story that stretches back to a time long before there were even stars in the universe" – cut to CGI shot of early universe, used in previous episode, purple glowing and pulsing cloud, with similar music, voiceover – "13 and a half billion years ago, just a few hundred million years after the big bang" – cut to purple and blue electric looking explosion (assumed to meant to represent big bang) – "the universe was a carbon free zone" – fade back to pulsing early universe clouds – "and infinite sterile gloom" – cut to another reused shot of purple and blue electric ripples – "of hydrogen and helium clouds" – cut to orange misty shot with clouds and what looks like an early star in centre - "until one day those vast clouds began to collapse under the force of gravity " – another bright implosion leaves a star like object – "and long before the solar system, earth or life existed" – shot of another star exploding – "the first stars were born"

08:51 – 10:02: cut to helicopter shot of desert-y scrubland, with dirt track and jeep driving down it, music is epic sounding with orchestral strings, and African sounding singing and drumming, cut to shot of jeep from helicopter alongside it see Cox driving, shot inside jeep, Cox piece to camera – "the birth of the first stars did much more than just illuminate the early universe because that set in train a sequence of events which ultimately is necessary for the existence of life in the universe" – cut back to helicopter shot of jeep, now in front with jeep driving towards helicopter, pulls back to reveal large empty landscape , voiceover – "and we can still see that process playing out in the universe today, cut to shot of jeep parked next to tarmac road, pans left to reveal large observatory building, voiceover – "this is the brand new south African large telescope" – cut to shot inside observatory of large set of mirrors suspended amongst metal frame, voice on walkie-talkie playing over top, another shot od telescopes mirror form higher angle, with mirror being rotated- "its mirror is eleven meters wide making it the largest optical telescope in the southern hemisphere" – close up of mirrors – "and it recently helped to pin down what's happening in an object some 650 million light years from earth"

10:03 – 11:00: shot of telescope image of stellar object, looks like two galaxies, slowly zooms in, voiceover – "this beautiful, almost lifelike system is known simply as the bird, it's the spectacular result of what we used to think were two galaxies colliding. Its events happening in the head of the bird that are most interesting from the perspective of" – cut back to Cox standing outside of observatory, sun setting over his shoulder – "life in the universe, because the head is formed by another galaxy, a third galaxy an island of billions and billions of stars colliding with the two galaxies that form the wings and the body at a speed of around 250 miles a second, now the turbulence the disturbance that that creates is causing many new stars to be formed" – cut to CGI shot of nebulous purple and orange clouds with glowing violet star at centre, pulses back and forth and become smaller and whiter,

11:00 – 12:34: voiceover of previous shot – "these stars begin their lives" –star glows brighter – "by burning hydrogen to produce ever more helium" – cut to much dimmer redder star with wispy red cloud surrounding it – "but as they age, as the hydrogen runs out, they turn to this helium"- cut to swirling red orange and yellow maelstrom of element symbols He is prominent in foreground (assumed to represent the inside of a star) – "the temperature at their core rises, increasing the chances of three helium nuclei fusing together" – this occurs on screen, 2 He's collide and become a Be and are then hit by a third to form a C– "to form a new element, Carbon" – other element symbols whirl past and there is a windy noise – "that process has been going on" – cut back to close up of Cox with sun setting over his shoulder – "for almost the entire history of the universe back through 13 billion years and it's the formation of stars that is the vital first step in the formation of life because stars produce the heavy elements in the universe including carbon" - cut back to CGI shot of gas cloud surrounding star exploding , then different t shot of star expelling wavy yellow lines, voiceover –"form the universes earliest times, carbon has been created in side aging stars" – cut o shot of star exploding entirely – "and over time" – shot of halo of coloured gases surrounding exploding star – "this carbon has built up, drifting through the cosmos as dust" – shot of dark misty clouds with glowing centre which revolves and increases in size and brightness – "until some of it was caught up in the formation of a planet called earth" – cut to shot of glowing centre with less thick gas clouds surrounding it, early solar system with planets trailing through clouds and sun in middle – "and it's here that we can see this ancient carbon brought vividly to life" – CGI shot of earth with sun at edge of screen lighting up small patch of land and sea, top of Africa and Spain and France, music reaches crescendo

12:35 – 13:41: cut to shot of darkness with large round light moving through trees, insect noise as in a forest, cut to different shot with large glowing globe being held by Brian Cox, lighting up small patch of dark forest around him, begins "today the universe is old enough" – cut to closer shot of Cox beneath the glowing balloon, from below looking up at him holding balloon above – "that countless stars have lived and died and so there's been plenty of time to synthesise the primordial hydrogen and helium into the heavy elements" – cut to shot of Cox walking through jungle with glowing balloon, through foliage – "the question now is" – cut back to Cox under balloon – "how does that carbon get into the web of life ? Well today it enters via one ingredient and I'm going to measure it using this balloon" – shot of Cox allowing balloon to rise into trees, becomes darker around him as light travels upward, same shot from reverse angle, voiceover –"the ingredient is carbon dioxide, which plays a key role in photosynthesis" – close up of Cox's face as he watches balloon rise, becoming darker as light fades, wider shot from higher up in canopy as balloon rise into tree tops –"each night the carbon dioxide concentration increases filling the air around the leaves at the top of the trees"

13:41 – 14:46: same shot of balloon in canopy as before, Cox begins –"now this balloon has got a carbon dioxide monitor in it" – cut back to Cox on forest floor, piece to camera – "which is gonna measure the change in the levels of CO2 at the top of the forest canopy as night turns to day" = Cox turns and walks away from camera, cut to shot of leaves at dawn, shot across canopy of sun rising above forest, voiceover – "as the sun rises the trees begin to photosynthesise. " "Now at 6pm last night just after sunset" – shot of balloon in canopy with stream in background – "the concentration was around 350 parts per million" cut to Cox standing on forest floor by balloon cord, holding piece of equipment looks like hand radio, piece to camera – "around 10 pm so four hours after sunset, the concentration had risen to around 400 parts per million and now, at about midday, the concentration" – shot of equipment Cox is holding as small screen on it, reads 'meter ch 1 – 345 ppm' – "is back down to about 3 4 5 parts per million, so that's a variation over a period of 18 hours" – Cox makes up and down wave motion with hand and a graphic line appears in the shape of a sine curve – "of around ten percent in the concentration of carbon dioxide jus in that piece of atmosphere at the top of the forest canopy, so what you're seeing there is photosynthesis in action

14:47 – 15:31: helicopter shot above jungle graphic sine wave tracks across landscape with helicopter shot, voiceover _ "everyday across the planet" – background fades to leave just shot of white sine wave on mostly black background – "photosynthesis uses sunlight to turn carbon dioxide and water" – background fades back in – "into simple sugars" – shot looking upwards at sunlight coming though misty forest canopy – "the overwhelming majority of the carbon is locked up" – cut to Cox standing next to a tree trunk – "in long chains of sugar, molecules called cellulose and lignin" – close up of tree trunk with graphic molecules overlaid, Cox continues – "now lignin is the stuff that gives wood its strength" – cut back to Cox by tree trunk – "so in this form and remember that is most if it, it is very difficult indeed for animals to access"

15:31 –16:24: shot of trees in forest with out of focus trunk in extreme foreground, foreground trunk brought into focus, voiceover – "for the energy and nutrients locked away inside these long carbon chains to move" – shot of Cox walking along path away from camera from low down on forest floor –

“through the food web they must be broken down” – cut to helicopter shot of savannah/grassland landscape, voiceover – “and the best place to see that process in action is out” – different helicopter shot of herd of migrating animals – “on the open plain. Its one vast larder” – closer helicopter shot of wildebeest/buffalo migrating – “for all manner of organisms” music strings tabbing, suggested motion movement, energy, cut to close shot of termites coming out of hole in mound, close up of termites head – “but by far the most effective harvester of carbon” – pull back to shot of termite on bit of mound – “is actually one of the smallest creatures on the savannah” – cut to close shot of log with termite running up it, has label attached, reads ‘Termite/ *Macrotermes ukuzii'* , other termites run up and down log – “termites are social insects” - shot of termites around hole into mound – “working together to form a characteristic” – shot of Cox from behind walking though bush – “sight seen all over the bush” – termite mound is revealed just beyond Cox,

16:25 – 17:33: he turns and delivers piece to camera – “that’s a termite mound actually it’s the tip of the iceberg the termite city extends way beyond that underground, and its function is fascinating , its essentially an air conditioning system, what it does is maintain very specific conditions inside the mound, the conditions of the rainforest” cut to close up of termite mound and a pick being swung into it, voiceover – “when the termites first colonised the savannah some 30 million years ago” – pull back to reveal Cox digging at mound with spade – “they brought the rainforest with them, to support a form of life that was already wonderfully adapted” – cut to shot of inside of termite mound through hole just created, Cox poking at contents with stick – “to living off dead wood.” To camera “And this is what these termite mounds are all about, can you see those structures there those white honeycomb like structures” – gesturing with stick – “those are called fungal cones” – close up of honeycombed piece of termite mound with small white balls in various places around it – “there wood pulp and possibly bits of dead grass that termites bring in and build into that structure and the reason the conditions” – shot of Cox squatting by termite mound looking back over his shoulder to talk to camera – “have to be the same as the rainforest is because they grow a particular genus of fungus called termitomyces around those honeycombs”

17:33 – 18:39: close up of honeycomb structure, pan left to reveal termite and label attached to white blob, reads ‘I’kowa/*Termitomyces’*, voiceover – “the job of that fungus is to break down the lignin and cellulose inside the wood” – close up of termite on bit of wood – “and convert it into a form that the termites can eat” – shot of broader area of honeycomb with lots of bits of white fungus dotted around –“which actually you can see there, there the little white” – close up on white balls – “nodules just present” – close shot different white fungus blobs – “on the honeycomb structure” – shot of termite with piece of fungus in jaws – “the termites lack” – shot pan left across wide stretch of honeycomb with fungus attached in various places and termites moving across it – “the enzymes to break down the wood efficiently so they’ve become farmers tending to one giant social stomach” – cut back to Cox in front of mound, to camera – “so there’s a very intense relationship between the termites and the fungus, you don’t find that fungus anywhere else, actually in the world, as far as we know , other than inside termite mounds” – close host of honeycomb structure with fungus, termite appears out of one of holes - “and its thought that up to” – cut back to Cox – “90% of the carbon locked up on lignin in this part of Africa is released back into the food chain again, solely by those termites and that fungus”

18:40 – 20:01: time-lapse shot of termite going in and out of hole in mound, time-lapse shot of a piece of mound being repaired or constructed , cut to shot of jeep travelling down road towards camera, through out of focus grass, cut to same shot with jeep further up the road, then closer shot with jeep even further up road, then more zoomed in shot can see Cox in passenger seat of jeep, cut to shot inside jeep looking up a Cox face and out into sky where sun is just visible beyond Cox, haloed with lens flare, shot of buffalo, music become more prominent, uplifting epic feel with African style singing, voiceover – “so the termites” – shot of Cox taking photo out of jeep – “deal with most of the lignin” – pan right to reveal small herd of buffalo”- but that still leaves a vast store of carbon in the form of cellulose" – cut to wide shot across savannah of huge herd of animals grazing with mountains and clouds in the background – "across Africa herds of mammals graze on grasses and leaves turning this cellulose into meat" – cut to shot of men riding in jeep from inside jeep, cut to shot of horned mammal grazing on bush leaves, shot of gazelle grazing on grass, shot of herd of gazelle – "many are a type of mammal known as a ruminant" – shot of Cox in jeep pointing, from outside jeep, cut to shot of two gazelle – "the largest of which is one of the easiest animals to spot" – moving shot form jeep of man riding on front of jeep – "on safari" - south African accent 'giraffe', cut to shot of giraffe form jeep, label attached reads 'Southern Giraffe/*Giraffa camelopardalis giraffe'* , cut to shot of Cox getting out of jeep, shot of giraffes through bushes, shot of Cox from behind looking at giraffe a little way off, giraffe seems to be looking at him and appears to be roughly same height due to foreshortening, shots of giraffes heads and necks, then different shot of giraffes seemingly tuning to look at camera

20:01 – 21:09: cut to shot of Cox looking at camera with giraffe in background, seems to be looking at him begins – "giraffes live off a diet that's similar to termites, they eat cellulose primarily actually the tops of the acacia tree's that you see here scattering the African savannah and they face that same problem , they've gotta break those difficult carbon bonds down, and they've come up with a very similar solution, which is to cultivate bacteria and fungi" – cut to shot of giraffes head and neck as it moves through bush – "but they do it inside their stomach " – more of the giraffes body is revealed and a graphic line drawing appears over the giraffes neck and body of its oesophagus and internal organs with four stomachs – "and ruminants like giraffes have had to build a very complex system in order to do that, they've got four stomachs" – labels appear on graphics of stomachs, read 'reticulum, rumen, omasum, abomasums – "one of them contains their culture of bacteria and fungi and they allow them" – cut back to Cox with giraffe behind him – "to digest that difficult cellulose" – Cox turns to look at giraffe, cut to shot of other giraffes grazing from bushes, voiceover – "even with all this hardware"

– shot of giraffe chewing – “ruminants must feed for over two thirds of the day” – shot of giraffes legs, pans up to rest of giraffe, finishing with head – “but there are other creatures here that have found a shortcut, after all if plant fibres are hard to digest, why not let someone else do the work and simply steal a meal?”

21:10 – 22:12: shot of leopard lying in long grass, well hidden, then shot over Cox’s shoulder form inside jeep of leopard approaching jeep, Cox begins “he’s coming or us, oh my god” leopard walks alongside jeep, camera follows it, different shot of leopard looking off camera, engine starting noise, cut back to jeep filming over Cox’s shoulder, now moving following walking leopard, Cox to camera – “look what we’ve just found” – points at leopard – “we were out looking for giraffes this morning we’ve found about ten of them over there” points over his shoulder – “but in looking for the giraffes we’ve just found a leopard, this is one of the top predators out here, he’s got very little to fear apart from other leopards and maybe lions he’s having a good look, he certainly doesn’t care about us” – cut to closer shot of leopard from stationary position, prowling across screen, looking off camera – “he’s around two years old and at the moment he doesn’t have” – cut back to Cox in jeep – “his own territory he’s two young for that and so he’s lying low”

22:13 – 23:08: shot of leopard in bush, stalking, engine staring noise again – “he’ll have to make about two kills a week” – cut back to now moving jeep following leopard – “to stay in good condition, so maybe catch er an impala every three or four days, he’s obviously doing that, because, look at him”- cut to leopard approaching jeep, Cox turns to camera then quickly back to leopard – “now he’s looking for protein, and I’m a little bit worried because I’m protein, oh wow” – leopard stops next to jeep can here in the background someone say –“he’s after your boom George” – Cox –“he’s coming really close to us cos he’s after the soundman’s boom pole which is, oh (laughs) that’s incredible (laughs)” – leopard runs off, cut to shot of Cox watching leopard in undergrowth

23:09 –24:11: cut to Cgi shot of very red sun, with yellow glowing crevices, shot periodically shakes, then to closer shot of surface of sun with yellow waves being shot off it, voiceover –"from its origin in the death of stars" – satellite shot of river system in lush green landscape on earth, music is familiar piano piece, peaceful, ethereal –"its capture by plants" – cut to shot of rhino on savannah, silhouetted against low sun on the horizon, lens flare hallows it – "through insects mammals and on" – cut to shot of Brian Cox in profile looking off camera, in last light of evening, out of focus as he turns to ¾ profile still not looking at camera, then turns back to profile to stare into distance, close shot of lion moving away from camera – "the carbon cycle is the real" – shot of giraffes grazing as the sun has just dipped below horizon – "circle of life" – giraffes all suddenly run off to the left, camera follows them, Cox continues –"out there tonight" – cut to shot of lion in undergrowth – "the relentless recycling of carbon through the food chain will continue" – cut to shot of Cox sitting on rock at top of small hill, small river valley below him with sun setting over the far hill behind him, piece to camera – "as night falls you can almost sense it the, the change in the sounds and the atmosphere"

24:11 – 25:22: shot of young lion walking away from camera, pans to reveal another lion, Cox voiceover – "some will die so that others can live as carbon leaps from branch to branch across the great tree of life" – shot of giraffes running through savannah – "guiding it on its way is just one very special form of chemistry" – cut back to close shot of Cox on rock, with setting sun in top right corner of screen – "every living thing is just a temporary home for carbon atoms that existed long before there was life on earth and will exist long after Africa and earth" – cut to shot of low sun sinking below low cloud on horizon, shafts of sunlight into camera – "are gone" – time laps of sun quickly setting – "but the pattern of life, the information needed to build a zebra" – cut back to even closer shot of Cox's face, background now out of focus – "or a tree or a human being or a lion persists, its passed on from generation to generation in a molecule, a, helical molecule with a backbone of carbon called DNA" – cut to shot long grasses silhouetted against last light of sun

,creating a rainbow striped affect across sky, bird song and piano piece as soundtrack, grass is brought of focus to reveal dead tree behind it silhouetted against sky, then cut to similar sky with a man holding a rifle silhouetted against it, music fades out, then screen fades to black

25:23 –26:24: cut to low shot of rocky floor with heat haze beyond, wind noise, then joy division song (chance(atmosphere)) starts, shot of feet approaching camera, synth and drum rolls, shot of Cox's face, approaching camera, voiceover – "there was a time when earth appeared empty" – cut to wider shot of Cox walking through scrubby desert landscape with hills in background, towards camera, joy division singing starts, fade to closer shot of cos still walking toward camera – "yet despite appearances" – fade to wider shot of Cox in desert landscape flat and featureless with hills in far distance – "3.8 billion years ago life was already underway in the form of tiny living specks" – fade to shot of thin blades of grass rising out of rocky dusty ground – "that probably all shared the same biochemistry" – cut to Cox in desert landscape, piece to camera – "we know that every living thing on the planet today, so every piece of food you eat, every animal you've seen, everyone" – shot of Cox in more vegetated area taking picture of goat like creatures – "you've ever known or will know, in fact every living thing that will ever -"shot of bird perched on bushy branch – "exist on this planet" – close up od tree bark and leaves – "was descended from that one –"pan up tree until sunlight flares and camera whites out – "speck" – cut to shot of coyote like creature in bushy grasses, looks up towards camera

26:24 – 27:45: shot of ostriches/emu walking through bushes, joy division song much more prominent, Cox begins –"we call it the last universal common ancestor" – cut back to Cox in desert, to camera –"or luca. So just as the universe had its origin at the big bang all life on this planet, had its origin in that one moment" – cut to CGI image of part of earth from space, text appears in corner of screen, reads '3.5 Billion Years Ago', voiceover – "less than a billion years after its formation there was already life on earth " – cut to close shot of rain falling onto stones on ground, then lightning striking through falling rain, close shot of droplets hitting crevices in rocks – "it's possible that some it used" – more shots of lightning striking –"biochemistry utterly different" – CGI shot of cell like objects, green, underwater - "from the life we see today. If so it has long been extinct. It's also possible that the first life may not" – screen fades to black – "have been cellular, just living chemistry" – CGI shot used in first episode of crack in rock with brownish 'cell' inside it – "in the porous ricks of some ancient ocean. We're not sure but what's certain is that one day, a population of organisms showed up with biochemistry we would recognise" – fades to CGI of group of spheres connected up white around edges with red cores, tendrils floating off at each end – "this was luca. The first expression of a form of life that would in time throw up a group of humans" – cut to Brian Cox walking across camera through scrubby desert lands towards rock outcrop – "who left their mark on this part of Africa"

27:45 – 28:49: shot from low looking up at rock face, early human pictures on rock face of people, sun above rock shining through cloud lighting up rock face and creating small amount of lens flare, cut to Cox standing by pictures on rocks, piece to camera – "now we don't know what luca looked like, we don't know precisely where it lived or how it lived, but we do know this, if you start to trace my ancestral line back to my parents" – music's starts, high pitched long notes, sounds ghostly and portentous – "to their parents to their parents to their parents, all the way back through geological" – cut to CGI 3d version of tree of life shows humans and primates then moves back down branches – "timescales, over hundreds of thousands and millions and billions of years, there will be an unbroken line from me all the way back to luca" – CGI tree is reduced down to one branch on which stands a blurred circular blob with LUCA written above it, then zoom fade to another shot of 'Luca' white and red blobs – "we know that because every living thing on the planet today" – zoom inside one of the red blobs to reveal black background with white model of DNA made up of four bases written out in words – "contains the same biochemistry. We all have DNA its made of the same bases A C T and G" – those letters at start of words light up- "they code for the same amino acids those amino acids build the same proteins" – screen flashes white and then cuts back to Cox at rock face – "which do similar jobs whether you're a plant a bacterium or a bipedal hominid like me"

28:49 – 29:59: shot of shadow of a wind pump on dry muddy ground, music is up tempo glockenspiel piece, cut to wider shot of run down farmstead, couple of horses, wind pump on right, sun rising over shill mostly silhouetting seen, voiceover – "so all life use the same fundamental biology" – shot of farmstead from different angle, Cox walking away from it, sun haloing him with lens flare - "those four bases A C G and T which code for just twenty amino acids" – coz continues walking and camera pans left to follow him – "which in turn" – cut to shot of large beetle walking across rock – "build each and every one of life's proteins" – cut to close up of stick insect on branch – "be you bacteria, plant, bug or beast, your design" – cut to shot of horses in front of ruined farm building – "comes from your DNA" – cut to shot of Cox walking up a rocky outcrop path, carrying small galls tank on black base – "so it's this molecule that must hold the key to understanding why life today"- cut to different shot of Cox approaching top of outcrop, walks past a crucifix erected on rock, cut to closer shot of Cox putting tank down, now on top of rocky outcrop with low lands and then hills beyond in distance – "is so diverse" – turns to camera – "we now know the answer to question why is life on earth so varied is actually the answer to question why is the DNA molecule itself so varied, what are the natural processes that cause the structure of DNA to change, well part of the answer actually doesn't lie on earth at all, it lies up there amongst the stars" – points up to sky –"and I can show you what I mean using this"

30:00 – 31:08: turns and indicates tank - "which is a cloud chamber, a piece of apparatus that has a unique place in the history of physics, I'm gonna cool it down" – cut to close up of polystyrene cool box being opened, contents is dry ice under paper _ "using dry ice" – cut back to Cox bending over box – "frozen carbon dioxide" – close up of Cox's gloved hands scooping dry ice up – "just below minus seventy degrees Celsius" – cut to Cox pouring scoop of dry ice into base below tank, puts the tank back in base – "I'll put the top on" – high pitched squeaking noise can be heard - "you hear that?" that's the metal at the bottom of the tank cooling down very rapidly, to minus 70" – cut to shot of Cox taping tank to base – "the cloud chamber works" – cut to different shot of Cox working on cloud chamber, from low with grass plants in foreground – "by a having a super saturated vapour of alcohol" – cut to close shot of Cox squirting clear liquid from a bottle onto a cloth – "inside the chamber"- places cloth on lid of chamber and squirts more liquid on to it" – plenty on their" – cut back to Cox's now _ "now I wanna get that alcohol, I wanna boil it off to get the vapour into the chamber" – cut back to low shot – "so I'm gonna put a hot water bottle on top" – Cox puts hot water bottle on top of chamber, cut back to previous angle, see Cox and cloud chamber – "I mean this is the first genuine particle physics detector it's the piece of apparatus that first saw antimatter, and it really does" – close up of tank with Cox leaning on hot water bottles on to – "consist only of a fish tank some alcohol, a bit of paper and a hot water bottle"

31:09 – 32:17: cut to shot if sky with sun peaking over close rocks, cut to wider shop of top f rocky outcrop, music is pizzicato string stabs, expectant and curious, cut back to Brian Cox with cloud chamber now has black cloth over it, Cox is holding a flashlight puts his head under cloth to look at chamber, cut to wider shot of Cox putting head under blanket on rocky outcrop, with desert scrub land and hills beyond, **emphasises natural setting of this experiment,** cut to shot of misty droplets falling against a dark background, trails appears though droplets, with accompanying whooshing sound effects to emphasise their appearance, voiceover – "there look at that, you see that cloud that vapour trail" – cut to wider shot from inside tank of flashlight illuminating the droplets and Cox looking into tank under cloth, to camera – "that's a cosmic ray, that was initiated by a particle, probably a proton that hit the earth's atmosphere", cut back to close up of droplets with trails appearing – "it almost certainly originated outside our solar system and was accelerated by the magnetic fields of our galaxy" – cut back to Cox's face looking into tank – "it may even have begun its life, beyond our galaxy"- music which was deep basses, ominous/portentous, suddenly lifts as cut to CGI of stellar explosion, then zoom into gases around explosion to pick out individual particles, quick cut to shot of galaxy zooms and spins around it, then zooms into galaxy to reveal shot of solar system, then zooms towards earth and then through earth's atmosphere down into the cloud chamber, then cut back to inside of cloud chamber close up of droplets with trails in them

32:17 – 33:16: "now imagine if one of those hits the DNA of a living thing what that will do" – cut to Cox's face looking into tank – "is cause a mutation that mutation may be detrimental or very, very occasionally it might be beneficial" – cut to helicopter shot circling outcrop looking at Cox with his head under cloth – "and I think it's quite wonderful to imagine" – cut back to Cox face looking in tank –"that maybe one of the key mutations that were selected for over the millennia, that led to some trait in me was caused by some particle" – cut to close up of droplets with trails – "that began its life perhaps in a massive supernova explosion, perhaps outside our galaxy and went and hit the DNA of something and caused" – cut back to Cox's face looking into tank – "some kind of beneficial mutation, we don't know but we can dream cant ya" – cut to helicopter shot of Cox coming out from under cloth, music is epic sounding, helicopter shot pulls further back to leave Cox as a small speck in desert landscape

33:16 – 34:42: voiceover – "mutations are inevitable part of living on a planet like earth" – cut to wide shot of herd of wilder beast on savannah – "there the first hint at how DNA and the genes that code for"- helicopter birds eye view shot wildebeest herd moving across plain – "every living thing change from generation" – helicopter shot out across savannah with trees and animals amongst grass – "to generation" – higher helicopter shot looking down at migrating animals, become like long lines stretching into distance, close up of spiders web, shot of rock jutting out of forest on hill with some kind of monkey on top of it, voiceover –" mutations are the spring from which innovation" –

shot of crocodile floating in river – "in the living world flows" – shot of Cox walking through forest, partly obscured by foliage – "but cosmic rays are not the only way in which DNA" – shot of hippo's in water, can just see their heads and snouts – "can be altered" "there's natural background radiation from the rocks" – cut to Cox walking next to camera, gives piece to it, "there's the action of chemicals and free radicals, there can be errors when the code is copied, and then all those changes can be shuffled by sex and indeed whole pieces of the code can be transferred from species to species so bit by bit, in tiny steps from generation to generation the code is constantly randomly changing"

34:34 – 35:47: shot of hippos in a river, voiceover – "now whilst there's no doubt that random mutation does alter DNA, evolution" – shot of Cox taking photo of hippos – "is anything but random. It can't be" – shot of hippos in river – "because the chances of something with DNA as complex" – hippo rises from water with label, reads' 'Hippopotamus/*Hippopotamus amphibius'* – "as this appearing by luck are alone are vanishingly small" cut to Cox standing by river, to camera – "imagine you just changed one position in the code at random, a random mutation" ' letter A appears on screen level with Cox's head –"there are four letters, A C T and G" – graphic letter scrolls through these letters, stops on g – "so there are four possible combinations. If there are two places" – another graphic A appears on screen next to first – "in the code there are four combinations for each one" – both letters scroll through different combos – "so that makes sixteen, if there are 3" – third letter appears, scrolling continues – "there are 64 possibilities. By the time you get to code with a hundred" – more letters appear in a line across the screen, all scrolling – "and fifty letters in it, then there are more possible combinations in the code than there are atoms in the observable universe " – cut to shot of hippo walking into river – "now a hippo has a code with around 3 billion different letters, so the number of combinations of those letters" – cut back to Cox – "the chances of producing that code at random are absolutely infinitesimally small, it's impossible!"

35:48 – 36:52: shot of hippos in river, voiceover – "so there must be a non-random element to evolution" – shot of Cox standing by river bank looking away from cameras zebras on opposite bank – "a natural process which greatly restricts this universe of possibilities" – pan down to hippos in river - "and shapes the outcome. We call it natural selection, and to see it in action"- wider shot of hippos in river with Cox on far river bank – "lets return to where we began, on the island of Madagascar" – cut to shot of sailing boat on sea, from land through leaves, fade to wider shot of boat looking small on sea with blue sky above, shot on boat looking up mast at sail and rigging, shot of Cox on boat, from behind him looking out to sea, sailors in front of him looking out also, slow-mo. shot of dolphins surfacing next to boat, shot of sailor at prow of boat as it approaches land, Cox begins –"around 65 million years ago a group of seafarers were nearing the end" – shot of bird in wicker cage on boat –"of a long journey across the Indian ocean"

36:53 – 38:24: cut to Cox sitting on boat, with two sailors lying on prow beyond him, piece to camera – "these were accidental travellers, a group of creatures from Africa trapped on a natural raft and carried by the ocean currents" – close up of prow of boat with land beyond, helicopter birds eye shot of rocky and vegetated coast, voiceover – "the land they found was virgin green territory" – helicopter shot of coast, not birds eye anymore – "plants insects reptiles and birds had established themselves-" shot of boat a t anchor with sail down, launch approaching shore – "but there were none of their own kind" – slow-mo. shot of Cox walking through surf to beach carrying poster tube – "they were caught up in a saga that tells of the great shifting of earths continental plates" – shot of sun light through tree leaves, lens flare, close up of iguana –"it's impossible to understand the diversity of life on earth today" – cut to Cox sitting on rock on beach, to camera – "without understanding the shifting geography of our planet, see here's a map" – picks up roll of papers from floor – "of earths southern hemisphere as it was 150 million years ago, and you see"- close up of map, large landmass in centre with label reads Gondwana –"its dominated by a single land mass called gondwana" – cut back to Cox holding map –"and then 90 million years ago" – puts down first map to reveal a second – "gondwana had begun to break up to separate into something that looks quite recognisably like Africa" –map has 3 labelled landmasses, Africa, Madagascar and India, - "and these two islands" – close up on map – "Madagascar and India. Now subsequently India has drifted northwards and bumped into Eurasia, raising the Himalayas, but crucially Madagascar has remained isolated it's been a an island surrounded by ocean for almost 90 million years"

38:25 – 39:34: CGI image of earth with continents in shape of gondwana slowly revolving then extremely quickly spins then slows to reveal the continents have changed position with Madagascar and India breaking off from Africa, same thing happens again and now India and Madagascar have separated, voiceover – "so when those seafarers arrived on their raft of tree's, and twigs" – earth shifts again now Madagascar and India in roughly their modern day positions – "and leaves they had a blank canvas, this" – shifts again and now can only see Madagascar and the coast of Africa as it is today – "this two three maybe even a single pregnant individuals" – cut back to Cox on the beach – "had a whole island to roam across, and over 65 million years they have blossomed into hundreds and thousands of individuals and become Madagascar's most iconic animals" – cut to shot of Cox walking up away from camera beach by small stream toward jungle, cut to wide shot of rolling vegetated hills with mist in valets between them in twilight, close shot of misty valleys in twilight, even more zoomed in shot of mist between a few stands of trees , label appears, reads 'Mitsinjo Reserve/Eastern Madagascar', cut to camera following Cox as he walks through jungle-y forest, there is a man a small distant ahead of him on track, cut to over shoulder shot of Cox stationary peering into forest canopy,

39:34 – 40:40: close shot of tree trunk, panning down, reveals an extremely well camouflaged lizard on trunk, voiceover – "finding the descendants of those ancient mariners" - cut to shot of lizard from different angle with Cox's face in background looking up at it –"is not easy" – cut to shot behind Cox as he continues through the forest –"but local guide joseph has been tracking them for years and is going to help me find them" – cut to close shot of Madagascan man, (joseph) looking into trees, then turning to look the other way, shot of Cox peering into tree tops, scanning shot up tree trunks to canopy until a lemur is spotted then focuses on lemur in tree, label appears reads 'Indri/*Indri indri'* , lemur looks about, begins climbing down, Cox begins – "there at the top of the tree is" – cut to close shot of Cox pointing into tree, to camera – "an indri, it's the largest lemur in Madagascar and its just sat" – cut to lemur in tree eating leave – "there watching us, quietly" – cut back to Cox standing beneath tree with lemur in, shot upwards to see lemur in tree as above him, piece to camera _ "this lemur here is a very special lemur he has a name, he's called David" – lemur climbs down the tree and Cox turns to watch, back to camera – "after Sir David Attenborough"

40:41 - 41:39: Cox approaches lemur in tree holding a leafy twig, joseph appears in shot under tree offering a similar twig to lemur, close up of lemurs face eating and staring intently, cut back to Cox below the tree, lemurs begin hooting and the lemur with Cox looks about quickly, cut to different shot of lemur as hooting continues, staring intently in one direction, hooting continues as lemur looks around, then pan down to Cox looking up at lemur, cut to different angle of lemur in tree, Cox and joseph below it framing the lemur on the tree, Cox turns to camera –"now we can only do this because joseph has spent a lot of time with these lemurs so they trust him, and therefore it seems they trust me" – Cox turns back to lemur who has turned to look at him, offers it the leafy frond, lemur looks quizzically at it and then turns away, joseph hands him a greener looking leaf, which he offers to the lemur who this time takes it keenly and begins to eat it, Cox turns to camera holding up his hand imitating lemur –"enormous hands"

41:40 - 42:38: cut to close shot of lemurs face in trees, looking intently – "the reasons for the find lemurs in Madagascar and Madagascar alone is" – cut back to Cox and Joseph below lemur, to camera – "because there are no simians, there are no chimpanzees, none of my ancestral family dating back tens of millions of years to out compete them, so what's thought happened is that" – cut to close shot of lemur hugging tree trunk – "around 65 million years ago, one of the lemurs ancestors" – josephs hand appears in shot offering lemur leaf, lemur takes leaf and begins eating it –"managed to sail across the Mozambique channel and when it landed here, there were none of those competitors here, and so the lemurs have flourished ever since" – cut back to Cox below lemur, holding bunch of leaves, to camera – "there are now over 90 species of lemur, or sub species, in Madagascar, no species of my lineage, the simians" – Cox offers leaf to lemur, hooting begins in trees and it quickly jump climbs away, Cox and Joseph watch it , camera follows it into trees tops

42:38 – 43:57: cut to close up of lemur howling/hooting in trees, voiceover – "over a vast sweep of time" – cut to shot of lemur jumping through trees – "the lemurs have diversified to fill all manner of different habitats" – cut to shot of white lemur jumping from different kind of tree branch, looks cactus like – "from the arid spiny forest of the south, to the rocky" – cut to shot of lemur walking along steep rock face – "canyons in the north, there is something about this island that is allowing" – cut to wider shot of lemur on rock ace approaching other lemurs – "the lemurs DNA to change in the most amazing ways" – cut to night time shot, with men with headlamps approaching camera up a muddy path, cut to shot of headlamp men walking past camera carrying large cage on poles, shot of more men walking past camera, then low following shot of men walking through jungle, head lamp beams lighting up small patches of ground, then man with torch walking into a more illuminated patch of jungle, then Brian Cox who stop in front of camera in bright patch, looks up into trees, cut to following shot of man through jungle, voiceover – "we're on the hunt for an ai-ai, the most closely related of all the surviving lemurs to their common ancestor" – shot of hand pointing into tree top, lit up by headlamp, camera shot into dark canopy, zoom on torch beam in trees, closer zoom on canopy, shot of Brian Cox shining torch into canopy, whispering – "oh yeah, yeah"

43:57 – 44:59: shot into canopy, can just make out furry shape, then moves and two red eyes are visible, cut back to Cox looking into trees, then to camera " just shone the light up and saw these absolutely two, great, bright red eyes shining out" – cut back to canopy shot, can just make out furry shape with red eyes –"she's very high up at the moment" – cut back to Cox – "they don't wanna lose sight of her in this forest, its very dark and dense" - cut to shot of a number of Madagascan men with tranquiliser guns and headlamps looking into trees and talking, voiceover – "the team have located a female ai-ai and her son" – cut to shot camera following Cox through jungle – "they want to attach radio collars to track their movements"- cut to close shot of man with dart gun looking to trees – "and better understand how far they range through these forests" – shot of torch beam in canopy – "but first they must sedate them" – cut to shot of man aiming gun into trees –"with a dart" – man is talking and lowers his gun, cut to Cox in jungle, to camera – "now what they've gotta do is wait for it to come down low enough to get that clean shot, I mean how you get a clean shot in this, I've no idea" – cut back to men aiming dart guns into trees, then men wand headlamps moving through forest

44:59 – 45:57: voiceover previous shot – "after 2 hours of traipsing through" – vertical shot if vines lit by torchlight into dark canopy above - "the treacherous forest, the ai-ai's remain at large" – screen fades to black, then fades back up to reveal morning daylight, with Cox and a few others back at a camp in a clearing, shot of Cox and a number of others sitting under lean to with dog, laughing and having breakfast, shot of Cox putting sugar in cup of tea/coffee, then shot of people carrying a cage across screen with Cox following them, then close up of furry creature (ai-ai), gloved hands raise its head, its tongue is sticking out and its eyes are half close, Cox begins –"well here is the aye-aye that was tranquilised" – label appears, reads ' Aye-aye/*Daubentonia madagascariensis'* – "last night. They finally got here about half an hour after we left" – cut to less close shot with Coxing holding aye-aye in gloved hands as it lies on a table under a lean-to, to camera – "I think it was because we were disturbing her, apparently as soon as we'd gone she came down the tree and she was tranquilised, and as you can see she's pretty well sedated now, which is fortunate for me, because she has certain adaptations that I wouldn't like to be deployed, you can see there, here teeth" – reaches around to pull down lip

45:57 – 47:10: close up of Cox's hand pulling down aye-aye's lip to reveal teeth, long and pointy lower front teeth – "her teeth are very unusual for a primate in fact unique, because they carry on growing so she's much more like a rodent in that respect and that's so" – cut back to Cox holding aye-aye on table – "she can gnaw into wood, you see aye-aye's have filled a unique niche on Madagascar, it's a niche that's filled by woodpeckers in many other areas of the world, what she does is she feeds on grubs and bugs inside tree's and to do that she has several unique adaptations of which her teeth are one"- close up of Cox holding ai-ai's hand –"the most startling"- separates fingers to show thin and bony middle finger –"is this central finger here, it's bizarre, it's got a ball and socket joint" – pan up to Cox's face as he examines aye-aye – "for a start, so it has complete 360 degree movement, it feels to me" – cut back down to aye-ayes hand with Cox moving finger around – "almost as if its broken, but it isn't, you can move it around in any direction, and she uses that finger initially to tap on the trunk of the tree and then " – cut back to Cox's face –" and then listening to the echo of that tapping with these huge ears" – cut to close shot of ayes face and ears- "she can detect where the grubs are" – cut back to wider shot of aye-aye on table – "and then she gnaws through the wood with those rodent like teeth, and then uses this finger again to reach inside the hole and get the bugs out"

47:11 – 48:24: close up of aye-aye's face, still with tongue out – "so the question is why?" – cut up to Cox's face – "how could an animal be so precisely adapted to a particular life style" – Cox looking at aye-aye who's eyes have opened slightly –"she's waking up now. And the answer is natural selection, see what must have happened is way back, when the ancestors of the lemurs, the lemuriforms arrived in Madagascar, there must have been a mutation that lengthened" – close u of aye-ayes hand – "the middle finger, ever so slightly in one of those lemurs, and that must have given it an advantage, that must have allowed it perhaps to reach into little holes and search for grubs, so some reason why that lengthened"- cut back up to Cox looking at his own hand – "middle finger, meant that that gene was more likely to be passed to the next generation and then down to the next generation, so that that landscape of possibilities is narrowed, its narrowed because that gene persists, and its persisted now"- aye-aye begins to move slowly on table – "for at least forty million years, because this species has been on one branch of the tree life of now, for over 40 million years, and so over those years, that middle" – close up on aye-aye's middle finger – "finger has got more and more specialised

48:25 – 49:33: voiceover over previous shot – "natural selection has allowed" – cut to shot of aye-aye being lifted by pair of gloved hands – "the aye-aye's wonderfully mutated finger to spread through" –shot of a man and woman examining aye-aye –"the population" – wider shot of man and two women examining aye-aye – "and this same law applies to all life, if you have" – close up of man with stethoscope examining aye-aye –"a mutation that helps you in the struggle to survive you are more likely" – cut to shot of aye-aye being examined by another man- "to leave more offspring and in the next generation" – close up on aye-ayes face – "that mutation is more likely to survive" – cut back to Cox holding ai-ai on table – "so this animal is a beautiful example probably one of the best in the world of how the sieve of natural selection produces animals that are perfectly adapted to live in their environment" – Cox looks intently at the aye-ayes faces, then cut to ai-ai being walking into cage, cage being closed, close up of ai-ai in cage, then night shot of headlamps moving through forest towards camera, cut to closer shot of men with torches walking though forest

49:34 – 50:35: voiceover of previous shot – "now there are many reasons to study the aye-aye but here's" – shot of cage being placed on forest floor – "a good one. In the 1970's it was thought the aye-aye was extinct" – shot of Cox looking at cage – “now we know that there are several thousand in the forests of Madagascar” – cage is surrounded by other people then door is opened” – 5, 6, 7 thousand, certainly less than ten thousand” – shot of open cage being placed next to a tree – “but over the last 50 years, 50 percent of this forest has vanished” – aye climbs out of cage and up tree, camera follows it as it climbs, - “this is an animal that’s been around as a” – cut to Cox on forest floor with men with lights and radio tracking antenna behind him, to camera – “species for 40 million years so it’s important to know how these animals are doing and how they’re surviving in this diminishing habitat” – shot of Madagascan man releasing aye-aye into tree and stroking its tails as it climbs, shot of Cox watching man do this, shot of aye-aye disappearing into dark canopy

50:35- 51:34: helicopter shot of brown jungle river in day light, voiceover – “whilst natural selection explains how the aye-aye evolved, it alone can’t explain how a small group of individuals, over 60 million years ago, gave rise to over 90 different species of lemur today” – cut to shot of Cox climbing rope into tree tops –“but there is another form of life that can offer us a clue” – shot form in canopy of leaves and branches and a large black ball shaped object hanging from a branch, Cox begins –“up here in the high forest canopy” – cut to Cox attached to tree by a harness in canopy, piece to camera – “we’re in a very different environment to the one down there on the forest floor, it’s a more arid environment, it’s almost like a desert, its exposed to the sun and water is harder to come by, and so this is a sea of different niches that are able to be occupied and exploited by animals that are different to the ones that you’d find down there” – points down at forest floor - “on the floor, so in very real sense this is an island, an island to be colonised”

51:35 – 52:41: close up of honeycombed structure, ants nest, with ants wandering over it – “and sure enough there are settlers to be found, even here” – cut to wider shot of brownish ball hanging from branch, Cox begins – “you see that thing that looks like a muddy ball there on the branch” – cut to close up of brown surface with ants on it – “well that’s an ants nest, its home to a species of crematogaster ants” – label appears attached to an ant, reads ‘

Ant/*Crematogaster hova-complex'* – "that are unique not only to Madagascar, but to the forest canopy, you see" – cut to shot of Cox hanging from rope next to ants nest in tree, to camera – "what makes those ants unique is that they can build their own nest, there are very few species of ant that can do that" – cut to shot of ants nest hanging from branch – "so that is an island, that is a niche and its allowed that species of ant" – close up of ants in nest – "to develop because they are isolated from the rest of the ecosystem" voiceover – "and astonishingly within this niche another form of life new to science has been discovered" – cut to extreme close up of insects feeler, then pan down to its head – a beetle that manages to survive here unharmed by the ants" – cut to extreme close up of different part of beetles anatomy – "how it does it is a mystery, but what is known" – slow zoom out to reveal all of beetles body – "is that this particular species has only ever been found inside these nests, fade to black

52:42 – 53:57: fade up to close up of ants nest, Cox continues –"so that really is its own mini" – cut to shot of Cox hanging b nest –"ecosystem, with species living in it that are unique to that island" – close sot of outside of nest with ants walking over it, music is recurrent piano theme used in earlier episodes, shot up of sunlight through tree tops, lens flare, bird and insect noise, cut CGI shot of sun moving out from behind earth, voiceover –"we live on an ever shifting dynamic world that creates islands" – cut to segment previously used CGI of Madagascar separating from Africa – "in abundance" – time lapse shot of clouds streaming over desert/savannah landscape, helicopter shot of rocky hills and mountains covered in lush vegetation – "earths mountain ranges, river valleys and canyons" – cut to helicopter shot of rocky bare canyon landscape –"all create islands for life –" more birds eye view helicopter shot of canyon, partially in shadow, closer shot of lemurs on rock face – "and its these islands that those ancestors of" – close shot of group lemurs hugging/grooming each other – "the lemurs found when they arrived in Madagascar" – shot of 2 red bushy lemurs of tree branch, close up of one of their faces, music has become more prominent, orchestral, grand and regal sound to it, cut to close shot of white lemur on spiky branch – "empty niches where populations became isolated"- shot of white lemur jumping from branch to branch – "and over great swathes of time evolved into such wonderfully diverse" – shot of white lemur hopping sideways on muddy ground –"forms" music crescendos

53:58- 55:03: cut to shot of small brown lemur through leaves eating something, then cut to close shot of darker brown lemurs face looking at something off camera, cut to shot of train yard used at beginning of episode, woman walking down tracks away from camera, shot of children playing front of run down house, shot of Brian Cox walking up path past house/shop towards camera, voiceover –"150 years on from the origin of the species the subtlety" – cut to shot of 2 boys playing in street " and beauty of Darwin's insight is still revealing itself to us," shot of Cox walking up train track, (same shot as beginning of episode, expect he is closer to the camera now) – "it describes how our beautiful complex tree of life has grown" shot of houses and people in front of them with railway coach in foreground obscuring part of shot – "from a once desolate universe" –shot of boy squatting and girl carrying bucket behind him – "the chemistry of carbon" – cut to Cox standing at railway platform, to camera – "allows for the existence of a molecule which is able to replicate itself and pass information on form generation to generation. There can be random changes in the structure of that molecule, mutations, and they're tested by their interaction with the environment and other living things. The ones that pass that test survive, and the ones that fail that test are lost"

55:03 – 55:51: shot of house, with washing hanging on garden fence and goose in front of house, shot of Cox facing away from camera looking down rail tracks, continues – "the separation and isolation of living things" – shot of man at water pump by tracks with woman carrying bucket back toward house and child playing in grass- "onto islands, which may be physical, like Madagascar or just" – cut back to Cox on platform – "the single branch of a single tree results in speciation the explosion of living things, highly specialised to occupy niches within niches and this is the explanation for the diversity of life on earth." – cut to closer shot of Cox on platform – "there is grandeur in this view of life as Darwin wrote, and understanding how it happened surely only adds to the wonder" – cut to slow-mo. shot of giraffe walking through bush, cut to shot of Cox facing away from camera looking at giraffe, who seems to be looking back at him

55:51 – 56:48: cut to shot of two lions licking each other, voiceover – "as precise as Einstein's theories of relativity and as profound" – cut to shot of Cox walking away from lion cubs on path (used earlier in episode) – "as thermodynamics, Darwin" – cut to shot of Cox taking pictures of buffalo from jeep (used earlier in episode) –"has given us another universal law" – shot of leopard walking across screen (used earlier in episode) – "evolution" – shot of Cox watching leopard from jeep (used earlier in episode0 –"by natural selection" – shot of zebra eating then raising its head to look towards camera, shot of Cox's legs and torso in foreground walking away form group of zebra, cut to CGI shot of earth, voiceover – "and if evolution is the law on this island then it will apply throughout " – CGI pans away from earth to look at sun, - "the cosmos" – then cut to CGI of earth and moon silhouetted against sunlight, then much wider shot of earth as tiny dot against small sun, with background of stars – "which begs a big question " – cut to shot of galaxy as the image pulls back as if travelling rapidly away from galaxy – "could there be other trees of life most beautiful" – shot of galaxy from above, can see almost all of it – "amongst the stars" – cut to shot of islands and sea, island silhouetted against setting sun, cut to shot of small hillock silhouetted against last light in sky, rock in front of it, with silhouette of man sitting on it

56:59 – 58:30: Cox begins over previous shot – "in 2011 we discovered a rocky planet" – cut to Cox sitting in front of silhouette of hillock, piece to camera – "orbiting around a distant star with day time temperatures not too dissimilar to those found on earth. Now there must be millions if not billions of such planets out there in the universe and its inconceivable to me that none of them will have trees of life as complex or even more complex than our own.

But that doesn't devalue the existence of our tree, because our tree is unique, it consists of thousands of branches all interdependent on thousands of others and the precise structure depends on chance events like the passage of the lemurs across the ocean 65 million years ago" – cut to shot of last light fading from sky over see from shore, tree silhouetted in foreground, Kate Rusby folk song begins, melancholy yet haunting and beautiful, cut to shot pan across hill top where small amount of light in the sky can be seen between clouds and hill, Cox continues –"so when you go outside tomorrow, just take a look at a little piece of your world, a corner of your garden or a park" – cut back to Cox on rock – "or even the grass that's growing in a crack in the pavement, because there will be life there and it will be unique, there will be nowhere like that anywhere else in the universe and that makes our tree from the sturdiest branch to the most fragile twig indescribably valuable" – cut to wider shot of hillock on small island with Cox silhouetted standing on small rock next to it, last light in the sky fading behind him, Kate Rusby begins singing, 'underneath the stars… , closer shot of Cox silhouetted against sky, small against hillock next to him but standing tall in nature, cut to final wider shot of Cox silhouetted against dramatic cloudscape with twilight sky, credits roll

Episode Ends

Bang Goes the Theory Series 7, Episode 1 Transcript

Key: L), J) and M) indicates talk delivered by the presenters of the programme:

L) = Liz Bonin,

J) = Jem Stansfield,

M) = Maggie Philbin

Other initials are used to indicate different speakers in each programme. In each case, who is being referred should be clear from the surrounding transcript.

Episode Begins*

00:25-00:39: L) “Without plastic the modern world simply wouldn’t work, it wraps our food, covers our cables and keeps us warm and its found in places you’d never expect”

Presenters standing on millennium dome

00:39-01:00: J) “what you might not realise is that the whole dome is covered in plastic-a Teflon coat. And it’s the properties of that plastic that help keep this the landmark it is, its relatively water and dirt repellent and also a surprising fire retardant. It’s just one of a whole world of uses of this remarkable class of materials

01:04-01:13: L) “but good or bad, plastic keeps hitting the headlines” shows headlines reading “parents panic after ‘toxic’ baby bottles banned by EU” and “poisoned by plastic” “tonight Maggie helps one family find out the truth about their exposure to plastic chemicals” cut to family and father asks “is anything leaching out the plastic into the cucumber?”

01:13-01:24: L) “I discover how plastic waste could get into our food chain” – shots of net in the sea and small bits of plastic floating on the surface of the sea – cut to Liz on beach with man in yellow waterproof overalls searching through seaweed on shore of beech who says “these sand hoppers will readily eat small bits of plastic, in fact there’ll even chew away at the corner of a plastic bag” – shows sand hopper to Liz who holds it for the camera and says “Oh my Gosh”

* The transcript begins at 00:25 seconds as the first 25 seconds of the transcribed recording shows the pre-programme BBC ident.

01:25-01:34: "Jem explores the latest in recycling and tries a new use for old plastic" shots of gem in a factory, sitting in a pile of debris hitting something with a hammer, putting plastic into a container, then shot inside container of something bubbling- cutaway to Jem leaning on exposed engine bay of car, holding a jar of liquid with hose running from it into car J) "This car is running on diesel that used to be plastic!" - close up of jar.

01:35-01:39: L) "and we meet a woman who's arm was fixed with the help of plastic glue" – shot of x-ray with a broken bone, then woman pouring what looks like PVA glue onto a petri dish.

01:39-01:44: L) "That's bang goes the theory on plastic" – shot of bang goes theory logo, cut to helicopter shot of cityscape (London) in the evening.

01:44-01:59: M) "plastic is practically everywhere, 260 million tonnes of it is produced each year. It litters streets, waterways and oceans, it's bad for wildlife, but is it bad for us?" – shots of plastic products; cameras, water-bottles, soap dispensers, man putting plastic in a plastic bin, shots of plastic waste in rivers and on beach with a seal and bird next to the plastic (*good contrast of nature and man – shows the negative impact plastic can have)* more shots of seal struggling with plastic waste, one trapped in a net another with a ring around its mouth/snout, shot of people in city one woman using her phone another man carrying plastic bags, person putting tomatoes on plastic bag.

2:01 – 02:22: Vox-pop interviews with members of the public, middle aged man: "I don't think we realise, jus, just how big this problem is", younger man in bow tie "cos obviously they wouldn't make it if it wasn't safe for you", older man with young girl (father and daughter) "we're using up the worlds resources to make it, if we can't recycle it, well, it's just wasted", "middle age woman with glasses "I think we've made such headway with plastics, brilliant what we can do with it" – cut to shot of land fill site with plastic bags blowing in breeze

2:22 – 2:35: J) "unfortunately a vast amount of our plastic waste still ends up in landfill" – shots of diggers moving plastic waste around on landfill sites - "but there is a good news story too" – shot of Jem walking towards industrial unit with 'closed loop sign' - "New technology is improving recycling all the time – that's exactly what's happening at this plant" – shot of Jem entering the factory

02:36 – 02:45: J) what's amazing about this place is within about 2 hours they're able to convert filthy bales of bottles into pure food grade plastic" – Jem delivers this piece to camera standing in front of crushed bales of bottles

02:47 – 02:56: J) "I've been given exclusive access to see how this plant manages to recycle a staggering 5 million bottles every single day" shot of Jem walking thought factory, bottles on conveyor belts, shots of tubing/factory machinery

02:57 – 03:18: "The sorted bottles are chopped into tiny flakes and all the glue and paper washed off" – pan up shot of large bag /hopper – "any stray bits of the mixed plastic are separated out" – wide shot of workers on factory floor, one driving a forklift – "the dense PET from water bottles sinks to the bottom, while the milk bottle flakes float and are skimmed off" – shot of machine with paddles turning in liquid, then close up of these paddles with white scum stuck to them – "then the milk bottle flakes get even more high-tech cleaning" – shot of Jem walking through factory looking around him inquisitively.

03:19 – 04:03: close up of cleaner looking machine with something pouring through it, pull back to Jem approaching machine then leaning on it, delivers piece to camera "Have you ever had that dilemma, as to whether it's better to recycle your milk carton with the lid on or the lid off? Turns out it doesn't matter, cos they've got one of these" – indicates machine he is leaning against, looks into it "it's a pretty stunning piece of kit, the, er , milk bottles and the lids are all shredded all washed and then drifted past a series of laser beams, the laser beams pick out which are coloured lids and which are white milk bottle and then micro air jets blow all the bits of lid away" – Jem makes a poking motion to illustrate this taking place – "so your left with that" – shows handful of coloured plastic bits to the camera "and you can see er you got your semi-skimmed – "holds green bit of plastic up – "your full fat" – close up on his hand with plastic bits in it – " and your skimmed" – holds up red bit of plastic – pull back to Jem leaning on machine - "and then all the bits of pure, shredded white carton, get sent off to the next part of the process" – Jem walks away to

04:04 – 04-21: close up of coloured bits of plastic, then Jem and man in high vis jacket standing by large hopper with handfuls of coloured plastic bits J) "what do these go on to become?

Man) Ah well actually they'll go on to become buckets, wheelie bins, you know we sell them, these are, ah, valuable commodity" – shots of both men holding handfuls of bits and brushing them with their fingers

J) Right –

Man) - that's why I love seeing the caps on

Jem) yeah, yeah, yeah exactly, nothing goes to waste – Jem gleefully pours bits back into hopper

Man) nothing goes to waste – said with enjoyment while point his finger as if making important point

04:22 – 04:33: J) voiceover – "until recently, plastic waste could never be purified well enough, but thanks to this final bit of kit, every dirty old bottle can at last be made back into a shiny new one." – shots of Jem and man walking away from camera talking, then close ups of machine, the digital control screen and then various parts of it.

04:34 – 04:48: J) "so what happens is, they get heated up and popped in a vacuum and it's almost like warming something up and chucking it into out space, anything that is not the plastic they want just gets vaporised, just disappears off it – Jem delivers this to camera, throwing his arms apart when he says the word vaporised,

04:48 – 05:15: close up of sign which reads vacuum pump extruder with green light lit underneath it indicating it is on, cut to Jem and man in conversation in front of machine, Man) "now imagine now, beautifully clean flake with no smell,

Jem) right-

Man) - we raise the temperature to 150 degrees Celsius, and we've got this molten mass of milk bottles running down an extruder" 0 shot of end of machine – its gonna come out like spaghetti out of there

Jem) – "whoaaa"

Man) "now look at that" – indicated machine, shot of plastic coming out of extruder like spaghetti

Jem) "I didn't expect that

Man) yup, that's what it is

Jem) that's like a playdough barber set

Man) it is!

Jem) laughs

Man) and effectively it'll start to chomp them up and turn them into little pellets" – close up of little pellets of plastic (05:15)

05:17 – 05:35: J) "well I guess this is it, quite literally the end of the line" – an holds bag of plastic pellets

Man) this is it, the loop is closed

Jem) and that's how, all those, dirty old milk bottles come out now – close up of bag

Man) recycled, food grade, high density polyethylene, ready to go back into milk bottles in the UK

Jem) that to me is astonishing

05:36 – 06:02: shot of old bottles in bales outside factory with forklift driver driving past - Jem) " and the same number of bottles will be made from this, as were recycled – more shots of large bales of dirty bottles – "it is very encouraging to think that between us the consumer, local authorities and industry like this, that we're beginning to tackle the mountains of waste plastic we produce" – delivered to camera in font of old bottles - "but not all plastic can be recycled like this yet" – shot of landfill site – "it's such a waste because it's made from the world's most lucrative commodity – shot of oil rig – oil."

06:06 – 07:34: shot of Jem in workshop holding jug of crude oil – "this, is crude oil, you can think of it almost as a soup of all sorts of different hydrocarbons. Now there are a huuuggge quantity of chemicals that are derived directly form crude oil. Now I've got two of them here" – picks up to tins of chemicals – "and the good thing about these two, is when you mix them together , you can make a plastic" – shot of Jem putting on rubber gloves – "chuck a bit of this in here – "pours some clear chemical into half a plastic bottle – "and an equal quantity of this" – pours brown chemical into bottle – "now when is start mixing this lot up" – said as he is mixing – "you get a chemical reaction in there, that starts making kind of individual molecules, join up into long, long chains, long chains called polymers, and that is essentially a plastic" – close up of mixture in bottle which has change from translucent to opaque and thickened – "the plastic that this makes, is called polyurethane, now that might sound like something you've never heard of, until, you realise that" – picks up a piece of insulation – "it's probably insulating your house right now, insulation panels; polyurethane" – shot of mixture in bottle begin to expand and foam " you may even be sitting on some polyurethane…I think it worked very nicely. Plastics are made in all sorts of different ways, this is just one of them. So if all these plastics are made from stuff derived from crude oil, is there a chance that these plastics can be turned back into something like crude oil? Or ideally something like petrol or diesel that can power vehicles – shot of polyurethane now finished expanding with song 'plastic man playing in background

07:36 – 08:52: "I'm going to try to cook up diesel from waste plastic - shots of Jem in workshop, using blowtorch, building something – "the first stage is to vaporise the plastic without burning it, so I'm making a superhot oven, and a cooking pot that's air tight and oxygen free" – shots of Jem making oven with previous as voiceover – "I've had to adapt it slightly, one more element to build" – delivered to camera leaning next to oven - "not only is a normal oven not hot enough for the process, a normal cooking pot isn't quite up to scratch either, so, I've built my own" – reveals heavy duty pot

08:06-08:41: J) "so the plan is to put my waste plastic into the pot here, the ideal cooking temperature is between 350 and 400 degrees" – shots of Jem flattening waste plastic, putting it in the pot - "Time to switch on the oven, lets cook some plastic" – shots of Jem turning on switches, close up of thermometer, "Soon it's going to get hot enough to start breaking down the plastic polymers that I placed in my cooking pot, at that point, they start forming flammable vapours, that are gonna rise up here " – indicates copper tubing which has been coiled – "into this condensing column, there, hopefully, they'll condense and cool, into some kind of liquid fuel, which we'll collect here" – indicates modified gas cylinder – "with the plan that we'll tap it off and run an engine off it" – all delivered in front of apparatus, whilst explaining how it all should work) – "as it melts the plastic breaks down into different length molecules, depending on the temperature" – shot of bubbling plastic in pot – "for diesel, I want molecule around ten to twenty atoms long"

08:53 – 09:14: shot of Jem switching on light, it has got dark so must be sometime later "right that's been boiling away for quite a while now" – shot of Jem tapping liquid of cylinder – "now let's see what we've managed to collect. Well it certainly looks encouraging" – holds beaker of brownish liquid, pours some onto floor, lights it with a match, it catches fire, Johnny cash's ring of fire starts playing in background – "well, there's no doubt we've made a highly flammable liquid fuel from waste plastic, the question is, will it run an engine?"

09:18 – 10:14: "I can tell my fuel is too flammable to be pure diesel, but with the help of some friendly chemists I can separate it out" – shots of fuel in laboratory, being subjected to scrutiny of man in lab coat, and then different process, heating cooling, cut to Jem outside a garage with jar of brown liquid – "so here's our diesel, or at least what we hope is diesel, these guys have kindly allowed us to put it in their vehicle, let's find out if it works, Kate are you alright to start her up" – the car is started by Kate, woman in driver's seat, jar of diesel connected to fuel pump – "keep going!" – engine is revved – "look at the level on that! "- Indicates jar – "it's dropped down! This car is running on diesel that used to be plastic, waste plastic at that!" – Shot of Jem lowering the bonnet, then in driver's seat - "Let's see how this goes" – drives car out of garage and down road

10:14 – 10:50: cut to all three presenter standing outside a modern building

M) "That was just so satisfying wasn't it? I can see how delighted you were!

J) Delivered to camera "I must confess I can that's not the best it can possibly be. Right on the cutting edge of research in this field, there are kind of universities and technology companies working on exactly this, and there's one company over n Ireland that's currently able to turn 1 tonne of waste plastic into 800 litres of fuel, and not like us, just a fairly sketchy looking fuel, they can actually specify exactly what they want, whether it's for cars, trucks or even aeroplanes" shot of aeroplane

10:50 -11:41: cut to Liz on snowy riverbank in London – "science is increasingly finding innovative ways to recycle plastic, but the fact is still far too much of its being chucked away carelessly" – shits of plastic waste on riverbank- and all that stuff ends up on our roadsides, in fields and on riverbanks like this one" – points at rive emphatically – "so what is that doing to the environment?" – another shot of plastic waste in grass, cut to graphic of pacific ocean with orange specks swirling in it – "plastic pollution in the pacific ocean in particular has received a lot of news coverage" – shot of plastic floating on see surface - "levels are so high there, it's been called the pacific garbage patch" – shot of dead bird with plastic in its carcass, close up on plastic in stomach of dead bird, shot of different bird with stomach full of plastic – "plastic is seriously effecting birds and animals in that area, but what's going on closer to home?" – shot of Liz walking towards a boat with man in sea-faring gear, in conversation "Professor Richard Thompson has been monitoring levels of plastic on Britain's coasts and in its waterways for the past ten years. – Shot of wake of a boat form the boat – "today he's taking me on a fishing trip with a difference down the Tamar estuary in Devon." - Shots of Liz and Professor on boat looking out across estuary, shots of estuary – quite attractive

11:45: 12:25: "So Richard how do you go about fishing for plastic?" – Shots of Richard and Liz on back of boat having following conversation

R) Well most plastics are buoyant when they enter the sea, we're gonna find them at the sea surface or close to it" – shot of sea surface, cut back to boat

L) OK

R) "so using a manta-net, like this on – we're gonna skim along" –

L) – "Because it looks like a manta ray" - L holds arms out like wings

R) "Yup, it's got these wings on it which will stabilise it at the sea surface" – leans on manta net, on the wings

L) "Yeah –"

R) "A large net which will trail out behind" – hold up net

L) “The water’s going through all of this

R) “Yeah

L) “And the plastic collects at the end bit

R) “yeah, the same kind of apparatus that’s used worldwide for sampling plastic at the sea surface” – shot inside the net

L) “And how much do you expect to catch?

R) “it varies, we’re one of the things we’re looking at is spring tides, neap tides, the tide, the flood tide, because what we’re wanting to understand is how important rivers like this are as a pathway for debris moving form far inland from fresh water, right out to sea.” – shot of professor talking to Liz

12:26 – 13:01: L) “ok they’re deploying – shot of men deploying net off back of boat

Men) 3, 2, 1, go” – drop net off back of boat, shots of boat from net’s perspectives

R) “over a third of the plastic we use, is used for single trip applications, we’re sort of taught that those a throwaway items, and, and that the plastic at the end of its life sort of has no value, and it’s that behaviour that results in littering, results in accumulation in landfill, results in debris being left behind by beach goers, and all of that material is accumulated in the environment” delivers as conversation with Liz but camera shot of professor. – More shots of boat

13:04 –13:53: shot of net in water – L) “this stretch of water is meant to be unpolluted, so Richard doesn’t expect to find much plastic if we’ve caught anything, its bad news” – shots of net being hauled in form another boat behind the one Liz is on, net being carried aboard and emptied, Liz) yeah, I can see plas– there’s a lot of seaweed but yeah, there’s definitely bits of plastic in there"- close up of bucket contents – "everything from , I don't know what this is but, but there small –

R) Yeah, the effects of small bits of debris are less well known and potentially quite different to those that we might think of in terms of larger debris causing strangulation or laceration. We've got very small pieces that could be could be trapped and, and retained. And there's also concern that some of these smaller pieces could act as ere r a vector for the transport of chemicals top the creatures that ingest them" – shots of L and R on boat, transferring contents of bucket to jar

13:55 – 14:49: shot of boat, voiceover Liz) "recent research suggests these tiny bits of plastic attract pollutants making them even more toxic to wildlife" – shot of L and R examining a jar with liquid in, looking pensive/worried - " all of this is bad enough, but it turns out it's not the open seas that are suffering the most – shot of L and R walking on beach – R) "so Liz the reason I wanted to bring you here was because some of the plastic we were looking at in the sea, well of course that all washes up on shorelines –

L) "Yeah – close up of professor with handful of shore debris

R) "if I dig my hands down, there's actually hundreds of – "

L) Look at that - "

R) Small pieces of plastic." – close up of professor pulling bit of plastic out of debris he is holding – "All of the shorelines we've sampled, worldwide, , right the way from the southern ocean up to the arctic we've found microscopic fragments of plastic on all of those shores." – blurred. Soft focus shot of the two of them from a middle distance + low down – cut to them looking in a different part of the beach

L) "Even if plastic breaks down into miniscule fragments it'll never disappear and now there's a danger it could get into our food chain, a food chain that starts with tiny creatures. – shot of them walking down beach as camera holds its position, walk off camera

14:50 – 15:24: close shot of professor digging through seaweed on beach with Liz standing over him R) "one of the ones we looked at was , these sand hoppers, will readily eat small fragments of plastic, in fact they'll even chew away at the corner of a plastic bag"

L) "oh my gosh. So these are the little critters that will be going through the really tiny plastic particles, is that right?" – shot from earlier with Liz holding sand hopper

R) Yeah, I mean they'd normally be shredding natural organic material, seaweeds

L) Yeah but so how much damage do we think this might be causing these little fellas?

R) "well that's really one of the great unknowns," – close up of sand hopper in Liz's hand – "and it's, it's something that we're really trying to establish and some of the research that we're doing at the moment is what is the potential harm from these microscopic fragments of plastic in the environment

15:25 – 15:40: shot of L and R walking of beach Liz) voiceover - "until we can prevent waste plastic from getting into our oceans it seems unavoidable that it will end up in our food chain. What we need to find out next, is how that might affect our wellbeing" – shot of river flowing into sea

15:41 – 15:58: shots of Liz in lab coat with another woman in a lab –M) voiceover – "Still to come, Liz finds out how PVA a plastic glues, is helping orthopaedic surgeons with bone grafts" shots of white substance being mixed in a bowl then on a shelf expanded, resembling a sponge. – L) "I'm really excited about this actually" – Liz in lab looking at something surrounded by equipment - "this is fantastic science"

M) voiceover – "but first back to our food chain" – shots of people with carrier bags and looking at food in containers in shops – "and whether we should be worried about plastic"

15:59 – 16:21: shot of millennium dome, followed by Vox pop with public, middle aged woman "most food products are wrapped in plastic aren't they, and you don't really know what's in it do you" middle aged couple man – "well it always strikes me as strange that you get lovely spring water and then you go and put in a petrochemical plastic container" shot of crowd, then woman "with breast cancer for instance, you don't drink the bottle of water left in the car in the sunlight and I've always taken that on board, I don't know how true that is"

16:21 – 16:32: shots of headlines from websites, can't see all of first most prominent word is killer, next headline reads 'the toxic time-bomb; researchers say gender-bending chemicals are rife but are they just the tip of the iceberg?', next one 'not so fantastic plastic; the dangers in bottles' next 'killers in your kitchen; gender-bending packaging, exploding floor cleaners and toasters more deadly than sharks…' M) voiceover "stories of harmful" – next headline 'bad chemistry; the poison in the plastic that surrounds us' - "chemicals from plastics have been in the news again recently – headline 'poisoned by everyday life' – "but is the media just" – next headline 'plastic chemical 'feminise boys" – "scaremongering, or should we really be worried?" – next headline 'poisoned by plastic: chemicals in water bottles and food packaging have been linked to infertility and birth defects. Scaremongering, or the truth?'

16:33 – 16:52: cut to shot of family M) voiceover – "like many families, the Nathaniel's from Nottingham are concerned because their life is full of plastic." Cut to child's eye view (peep show style) carrying plastic thing - "But do they really know how harmful it is even in their own home" – shot of father in kitchen sped up, then shot of family carrying things outside – "I've asked them to collect as much as they can and pile it up in the garden" – shot of mother in study moving things and piling them up, mother – “there’s so much I can’t decide what to put in” – M) voiceover “ but after – shots of child in bedroom looking for things – “just a few minutes it’s clear that this could go on forever.”

16:53 –17:28: cut to family outside with M in front of pile of plastic goods M) – “Do you know I am gonna stop you there ha-ha, cos your just decimating your house, erm what haven’t you bought out?”

Mother – “we haven’t bought out the fridge” – close up shot of things in pile

Father – the washing machine, printer”

M) “and obviously we’re not going to ask you to start bringing out all of the cabling and all of the lighting and the things which are actually fixed” – more shots of things in pile – “but there were some things there that you didn’t pick up umm for instance fleece” – holds fleece up, shot of mother looking surprised but accepting – “and tin cans”

Father – “where’s the plastic in the tin cans?”

M) - “its, inside

Father – oooh – noise of surprise

M) voiceover – “yes plastics are in practically everything, but it’s the stuff that comes into contact with our food that really worries the Nathaniels.” – sped up shots of father putting things in fridge

17:29 – 17:58: shot of family around the table in front of a laptop mother – “Ok so we don’t use Clingfilm, erm we cook in ceramic containers

Father – “we buy bottled water, we will recycle the bottle we won’t reuse it

M) voiceover, shots of previous headlines on screen – “the Nathaniels worries started when they read news stories linking chemicals in plastics with hormone problems. In particular it's known that two ingredients found in everyday products" – shots of headlines with bisphenol A and phthalates – "bisphenol A and phthalates can affect our sex hormones. So the Nathaniels want to know which products are safe to use" – shot of variety of plastic products on table

17:59 – 18:32: cut back to family around table, mother: "so starting off, mineral water is it safe when we get it in a bottle like this and what about when we reuse the bottle several times?"

Father: "buying cucumbers wrapped in plastic, is there anything leaching form the plastic into the cucumber?!

Mother: "and we also drink our water out of reusable bottles, are these safe, what about food boxes, is anything leeching out of this into our food?

M) voiceover – "so I've arranged some tests" – cut to courier at door – "I'm sending urine samples for analysis to find out if we have any plastic chemicals in our systems. But to answer their questions about bottles and containers I need to see an expert."

18:33 – 19:30: shot of M and man walking down road toward camera – M) voiceover – "Dr Chris Howick is a food contact expert for the British Plastics Federation" – inside room with bag full of plastic things

Dr H) "if your family is particularly concerned about things such as er bisphenol a and phthalates erm this is not er based on bisphenol a" – said whilst holding a plastic water bottle – because it's a rigid plastic er it won't contain phthalates, so er I think we can give them the necessary reassurance on that one.

M) "There's one query about reusing plastic water bottles, I mean this is something that I do all the time

Dr H) "yes as do I, I mean as long as it's kept clean and that it's, the integrity of the plastic article remains that it can't still be used

M) “ok great, and what about the plastic” – hands him a cucumber wrapped in plastic

Dr H) the great thing about plastics for erm packaging cucumbers is the plastic would have been through the assessment so it would have been shown to only use the approved, er, ingredients and also the great thing here is that it that it extends the shelf life of the cucumber form 3 days to 14 days”

17:59 – 18:32: M) voiceover, shot of close up of symbols on plastic packaging – “Chris told me that all plastics used to package food are tested and labelled appropriately, including whether they can be used in dishwashers or microwaves” – cut back to room with M and Dr H

Dr H) “there a huge safety obligation that the regulators place on the plastics industry, companies have to only use the materials that are approved and they have to do testing on a regular basis to show that even those substances that are approved do not transfer the er ingredients into food in any levels that can ever be considered a risk to public safety”

20:05 – 21:13: cut back to shot of family outside front of their house M) voice over “it’s time for the Nathaniels and me to find out whether everyday contact with plastic means we have the chemicals in our systems” – cut to interior shot of family around table – “and if so, whether the levels are safe or not.” – M) Now talking to family around table – “all of us had levels of BPA, very small amounts, but detectable levels of BPA, and you guys” – indicates father and oldest son - “had tiny amounts of phthalates”

Father: right

Oldest son: just me and him” – indicating father

M) Just you two” – pointing – “yeah. Just to reassure you that even if you’d had 250 times the amounts that showed up on our tests you still would have been alright. We’ve had every assurance that they are very, very safe levels umm you know really miniscule levels, I just wondered how you felt about that?

Father; "it's nice to know that plastics are safe and that what we've found in us is not out of the ordinary

M) "And will you change anything as a result of this" – asking mother

Mother; "well I'm very, very pleased to know that I can keep reusing these water bottles cos that's very, very useful

Father: "and I'm going to read the manufacturer's instructions more carefully" – everybody laughs

21:15 – 21:34: cut to M) in a studio space, delivers piece to camera – "the two types of chemicals that we looked at with the Nathaniels have been well studied and shown to be safe at the levels to which we are normally exposed, but since we made that film a new report from the world health organisation and the united nations environment programme has hit the headlines. I caught up with one of the authors to discuss the findings"

21:35 – 22:58: shot of M and women walking down corridor towards camera in conversation, shot of newspaper headline "landmark study warns gender bending chemical's in your home, food and car ARE linked to a huge range of diseases", voiceover begins talking as this headline lingers on screen – "so the report summarises the result of over a decade" – cut to woman in offering this piece to camera, 2 white-coated men at benches in front of equipment in background, title says woman is "Prof Susan Jobling, Brunel University" – "of work on endocrine disrupting chemicals. These are chemicals which interfere with or mimic the action of hormones and in so doing cause adverse effects on bodily functions." – shot M) also in lab from over the Prof's shoulder, asks the following question – "Are we likely to be exposed to levels of these chemicals which could have an adverse effect? –cut back to shot of Prof J –

“there are 143,000 chemicals in commerce” – shot of text, possibly from article with first line reading ‘Close to 800 chemicals are known or suspected to be capable of interfering’, text above and below is blurred out – “and of those currently we know there are about 800 which may be endocrine disrupting chemicals” – cut to a shot of different text describing where these chemicals are found and how they can be transmitted into and through the environment – “these chemicals are everywhere, they’re in our food, they’re in our furniture and they’re in cosmetics. What this means” - curt back to Prof J in lab - “ is that we experience exposure to diverse chemicals from various sources as a cocktail and that whilst individually these chemicals may not cause harm collectively they may have already reached harmful levels” – cut to shot of article text, top line contains the words ‘significant uncertainties about the true extent of risks from chemicals – “many diseases and disorders in modern day society that are endocrine disorders” – cut back to Prof J in lab – “such as reproductive cancers, like prostate and breast have risen over the last forty to fifty years and that this rise has been too steep and too fast to be explained” – cut back to text about speed of rise of diseases – “by genetics alone. Environmental factors are generally accepted to be involved”

22:59 – 23:21: cut back to M) in recording studio space, delivers piece to camera – “it’s not hard to see just how complicated this is. On the one hand you’ve got exposure to a vast number of chemicals and effects on the body that might take decades to manifest themselves. It’s clear that much more research is needed and in the meantime we have to way up the potential risk against the very real benefits that plastics can offer.”

23:22 – 24:33: cut to shot of feet walking along a muddy path, L) voiceover begins – “one area where plastics can be advantageous is in modern medicine” – cut to reveal it is woman walking along path – “as Kerry Adams discovered – “cut to woman riding horse – “she’s always been a keen horse-rider, but in 2008” – close up of horses feet trotting – “suffered a freak accident” – Kerry’s voiceover begins – “I was having a riding lesson – cut to Kerry standing in countryside setting in front of field with sheep in – “my horse shied and I lost a stirrup and then I felt his haunches go and I knew I was in trouble he was gonna bolt" – Cut to close up shot of stirrups looking out on practise yard, ominous sounding music K voiceover continues – "the next thing I remember I was in hospital. I'd broken both my arms" – cut back to Kerry continues delivering piece to camera – One bone in my right arm both bones in my left arm which was bent at 90 degrees" – shot of x-ray of broken arm with both bones broken, cut to a shot of x-ray of arm with a plate holding the bones together, L voiceover begins "Kerry had extensive surgery on both arms, leaving her with plates and screws holding her wrists together. But a year later she was still in pain" – close up of x-ray with plates and screws in both arm bones, Kerry voiceover begins "so the doctors decided" – cut to Kerry walking down country path towards camera – "that is was unlikely to heal so they suggested a bone graft" – cut to shot of operating theatre with medical team conducting operation, L) voiceover begins - "to produce a bone graft surgeons normally remove a piece of healthy bone form another part of the patient's body" –shots of surgeons at work, instruments, then shot computer screen with scan images of a pelvis – "usually the pelvis." – cut to Liz standing in lobby area of a building, delivers piece to camera –"but there is another option that is far less invasive and painful and that is to produce a synthetic bone graft. Now the key to making that a successful alternative lies in a plastic that's derived from this stuff2 – holds up a white bottles – "school glue".

24:33 – 25:30: shot of contents of previous white bottle being squirted onto a petri dish being held by a woman from below the dish, contents look like PVA glue, L) voiceover begins – "Dr Karen Hing from" – cut shot of Karen and Liz entering lab space in white coats– "Queen Mary's university was on a mission to find an artificial substance with the same special properties" – close up of material, which could be bone, very spongiform, lots of holes – "as bone. It has to be light and" – even closer shot of the structure of the material – "and strong, with a honeycomb" – transition from close up to microscopic image of structure of material made to look like the camera had zoomed in all the way

– “that allowed real bone cells and blood vessels to grow into it creating new bone.” – cut to close up of Liz in lab coat asking following – “so how did you go about making the perfect synthetic bone graft ?” – cut back to both women standing at lab bench with chemicals, instruments on it, Dr H replies – “we use, Poly Vinyl Alcohol” – shot of L) face smiling knowingly – “its derived from Poly Vinyl Acetate” – cut back to shot of both women – “which is the basic ingredient of school glue

L) Right –

Prof H) PVA

L) So, polymer

Prof H) um hmm –

L) What is this?

Prof H) so that’s your calcium phosphate so this is the hydroxyl appetite with a dash of silicon in there

L) Pinch of silicon

Prof H) pinch of silicon, yup

L) And that is chemically, very similar -

Prof H) - yeah -

L) – to our own natural bones

Prof H) exactly”

Shots of various chemicals just discussed being poured into a mixing bowl

Prof H) so just a bit of pure water” – shot of prof pouring water into measuring tube – “and do you want to pour that in

L) “Go on then “– pours water into bowl

Prof H) and now, if you can give that a mix together with the whisk" – shot of Liz mixing, then close up of whisk in mixture

25:30 – 26:17: more shots of mixing bowl with contents being mixed L) voiceover begins – "I'm after a thick foam but all my whisking is pointless so far, and that's where the magic ingredient comes in" – cut to shot of women in front of desk, prof pouring a chemical into a measuring tube, L) asks her "So what's, so this is the poly vinyl alcohol"

Prof H) yup" – pours contents of tube into rest of ingredients

L) 20 mils or so, and then whisk away is it?" – Liz continues to mix, shot of both women looking into the bowl, smile appears on Liz's face

L) "Look at that" – shot of bowl where mixture has begun to foam

Prof H) obviously you want it to foam up like a meringue" – shot of bowl, where mixture is foamier

L) Oh, look that's amazing, I thought that only happened with egg whites" – cut back to shot of women behind bench - "how does the poly vinyl alcohol mm make this happen, this frothing effect?"

Prof H) "it's more or less exactly the same thing that happens when you do your washing up" – shot of Liz's face smiling and nodding - "the poly vinyl alcohol is reducing the surface tension of the water which means that when you whip it up the bubbles form and then they don't collapse again" – shot foamy liquid in mixing bowl"

26:18 – 27:09: shot of liquid being poured into a mould in a tray, L) voiceover – "to turn this frothy liquid to a bone like substance" – shot of mould being placed in cabinet – "we need to gently dry it out at a low temperature" – shot of finished product, resembles a sponge, in petri dish – "just like this one Karen made earlier" – shot of finished one being taken out of cabinet, L) in conversation with Prof K), L) - "may I lift this?"

Prof H) yeah" _ shot of it being carried to table

L) "I'm really excited about this actually, it's just fantastic science " – shot of Liz examining graft, crumbling bits off it – "this now represents a very bone like graft

Prof H) yeah

L) "That you could place in a fracture, to allow the natural healing process to occur"

Prof H) "exactly. So the next thing we have to do is fire it just like you fire a ceramic pot and then, the ceramic particles will fuse together as the temperature gets hotter" – shot of graft being placed in then removed from oven – "and then that gives it its nice solid structure and integrity" – cut to the 2 women behind bench" - but because of the way that the PVA has foamed it you've still got that macro structure and the micro-structure that we need to have that porosity for it to work as a bone graft"

27:10 – 27:47: close up of graft in petri dish, L) voiceover – "one final hot firing burns off all the PVA leaving a synthetic bone graft that's plastic free to put inside the patient and this is how Kerry's bones were fixed" - song "them bones them bones them dry bones" playing in background, cut back to Kerry, revealing scars from surgery on arms, she begins - "I went to have an operation and they put the bone graft in the fracture site, sewed it up and sent me home. Finally, three years after the accident, I had the plate removed" – cut to shot of Kerry riding a horse around practise yard – "and I'm back riding again" – 'bones' song continues playing, Kerry voiceover of shots of her riding – "I thinks it's great that they've found a way of using an everyday material like glue to help make a synthetic bone graft" – shots of Kerry smiling with her horse, word hallelujah being sung is louder than rest of soundtrack

27:47 – 28:13: cut to shot of a thin plastic screen being bent, with song 'bend me shake me anyway you want me' playing, M) voiceover begins – "Plastics are transforming life beyond medicine too" – shots of computer chip being put together, more thin bendable screens – "especially in new media, like these completely flexible screens, with revolutionary plastic electronics" – cut to Jem, delivers piece to camera – "But, cutting edge plastic research is not all in electronics, no no, there are people out there who've invented a new plastic polymer chewing gum apparently it tastes like the real thing, but just doesn't stick to the pavement" –

28:14 – 28:29: cut to shot of the bang goes the theory website, Jem voiceover – "visit slash bang to watch me making plastic from potato starch, and for even more on plastic, follow the links to the open university" – shots of OU website, cut back to all three presenters in a café around a table, L) delivers piece to camera – "that's all from us on Bang, we'll see you same time same place next week, take care

Jem) good bye

M) Good bye

Episode Ends

Bang Goes the Theory Series 7, Episode 5 Transcript

00:00 – 01:21: opening shot of J and L standing with backs to camera at market stall, both turn to camera, L begins – "welcome to Bang! Goes the theory bringing you the science behind the headlines and tackling the issues that affect all of our lives" – cut to shot of newspaper front cover with 'Burger meat 80%' visible, J voiceover begins – "the discovery of horsemeat in beef" – cut to shot of different newspaper headline 'Frozen beef lasagne was in fact 100% horse meat' – "products earlier this year has prompted" – different newspaper headlines 'Horse could be in school meals' – "some serious investigations. It's also been a veritable feast for the headline writers" – cut to newspaper headline 'the British horsemeat scandal' – "On the whole it's a story of deceit" – cut to J given piece to camera in market – "someone somewhere in the supply chain passing the food off for something that it isn't" – cut to L standing next to J, delivers piece to camera – "and it has brought up a lot of questions about the food industry" – twitter tag appears on screen – "making us think more about what we're eating and where it comes from, but for answers you need to look at the facts, and that's where the science comes in, so tonight we're lifting the lid on food technology" – cut to shot of splint being lit in a candle, J) voiceover begins – "coming up, I investigate the invisible tricks used to keep our food fresh" – shot of glowing splint being put into a plastic meat package with small hole cut in top, splint bursts back into life, J) – "woooah, look at that" – voiceover continues – "Maggie finds out" – shots of M in lab looking at computer screen with graphs on it –"how science can add gourmet flavour to bland food" – shot of woman scientist in goggles and lab coat, talking to M, woman scientist says – "it's really got a nasty aroma, but its required" – shot of M in goggles n lab coat nodding – "you need to have it there to give you that fried steak" – shot of steak being flipped in pan – "aroma" – cut to shot of L in kitchen with man behind desk with a variety of small bowls on it, J voiceover – "and Liz discovers the weird things added to our foods to keep it looking good" – close up of items on tables, in foreground bowls of white powder with labels 'mono and diglycerides of fatty acids', 'polyglycerol esters of fatty acids', close up man's hand picking up bowl behind label which reads 'cake gel emulsifier', man begins talking – "and what you get is this almost soapy material" – holds bowl up and he n L rub small amount of lard like substance from it between their fingers – "now what this is designed to do" – shot of Liz stiffing substance – ""is kind of the same thing that the egg does" – close up of bowl of eggs, J) voiceover – "that's bang goes the theory on processed food" – Bang goes the theory logo appears

01:22 – 02:21: shot of ready meals being put into trolley filmed form camera in trolley, in quickened time lapse style, L voiceover – "Recent news reports have really made us question what's in our food" – vox-pop with 2 women outside in high-street – "I'm not that concerned about eating horse, but I am concerned about the labelling issue so if you buy something that says 100% beef that's what you expect it to be so there's definitely a trust issue there" – cut to different middle aged women given vox-pop – "the general public are fed up with being conned now, and they feel conned by the food manufacturers and they're making a lot of money" – vox-pop with different middle aged woman – "absolutely shocked because if they can do that to food they can put it, put something else, they can put other things into food that we're not aware of," – close up meat hanging in abattoir, L) voiceover – "when it came to exposing the horsemeat fraud, the forensic" – shot of lab-coated and gloved individual pipetting substance into vials – "weapon in the limelight" – shot of computer screen with graph on it with DNA letters A C G T all visible – "was DNA analysis" – close up shot of vial with liquid in being held up to light – "without this technology" – cut back to supermarket trolley shot – "identifying minced horse meat in food would have been impossible, but the horse meat scandal is small" – shot of neon sign reading 'fish' – "in comparison with what goes on with fish" – cut back to empty trolley – "the food standard agency has revealed that one" – trolley is filled with various fish products – "in ten fish dishes are not quite what they seem, so I'm making my own mystery fish pie" – cut to close up of fish being sliced, then shot of L) in kitchen preparing pie – "to find out how they're investigated".

02:22 – 03:14: shot over L)'s shoulder of chopping board with a number of different kinds of fish and L cutting some more up, close up of fish on board, L begins piece to camera – "quality fish simply isn't cheap anymore and food manufacturers have been substituting fish like prime north Atlantic cod for example in ready meals like fish pies, for cheaper alternatives, and that's where DNA analysis comes in" – shot of L) preparing pie, voiceover – "DNA testing for fish is so advanced it can identify over a thousand different species so in theory it should be virtually impossible for a rogue species to make it into a dish, but is it?" – Cut back to Liz finishing the pie, piece to camera – "OK so in this pie are several different types of fish all bought on the high street, one of which is a rogue species that's often substituted for cod." – shot of L) placing flag in pie which reads 'red herring pie', voiceover – "the question is will DNA analysis be able to identify all six species correctly" – close up of pie flag – "we've sent our pie to one of the top fish genetics labs in the country, at Bangor university"

03:15 – 04:07: shot of lab, white coated men behind bench with lots of bottles and equipment, another white coated man brings in cool box says – "Ok here we have the mystery fish pie" - -shot of pie filling being uncovered, L) voiceover –"the first stage of their analysis is to extract" – shot of smaller hunk of fish and potato being separated carefully with pliers and tweezers – "and clean the fish meat" – shot of small bit of fish being places in bottle with tweezers – "the fish DNA is extracted" – shot of pipetting into vial – "using ethanol " – shot of white coated and gloved man examining vial – "then a specific gene" – close up of vial + its contents – "which is present in all fish is pinpointed" – shot of vial being placed in rack – "and using PCR a sort of molecular photocopier" – shot of gloved hand using computer mouse, then shot of computer screen showing BW picture of lines and columns, resembles barcode slightly (assumption is it is PCR output) – "millions of copies of this genetic bar code" – close up of PCRE picture – "are made. By reading that bar code they can identify the exact" – shot of pieces of fish on board – "species of fish" – shot of M) approaching modern building, L) voiceover continues – "Maggie has gone to Bangor to get the results from professor Gary Carvallo who runs the lab" – shot of lab from outside M) begins – "I can't wait to find out whether you've identified the fish in our pie" – male voice, GC, responds – "this mystery fish neither can I, I'm more anxious than you are!" – M) laughs

04:08 – 05:07: shot of M and GC in lab, both in lab coats, surrounded by equipment and chemicals, in front of computer GC) – "Ok so based on what we could see in terms of the colour and the texture of the chunks in the fish pie, we actually" – close of M nodding – "actually think we have six different" – cut back to previous shot – "species of fish"

M) – “and that gets the first big tick, cos as you see on our fish chart” – indicates flip chart with six silhouetted fish which was previously out of shot though which GC would have been able to see – “there are six species, but have you correctly identified them?” – shot of computer screen with graphs on it

GC) – “when we get the data back we have a trace of the sequences” – close up of graphs on screen –

M) – “so that’s one fish there?”

GC) – “this is this is the trace from one fish , and essentially the DNA is an alphabet of just basically four letters and it’s the combination and the order of those letters” – shots of different window being opened on computer and file with a long string of a c g and t’s being opened – “that collectively will tell us” – shot of DNA text in text box – “the specific species and over a third of fish species” – cut back to first shot of GC and M behind desk – “have now been barcoded and they’re” – shot of webpage with map of world with various locations having red dots on them – “in the reference database, so it means we can take our mystery unknown sequences” – back to previous shot – “drop them into the database and then search for a match” – cut back to pc screen – “so what it is telling us with a very high level of certainty, its telling us that the first piece of tissue that we extracted DNA from belongs to Atlantic salmon” – shot of computer screen with writing ‘Top Hit: Chordata – Salmoniformes – Salmo salar (100%)’ , shot of M pealing of one of the silhouettes to reveal a picture of a fish labelled salmon

M) – “tah dah”

GC) – “we have an Atlantic salmon, very good very good”

05:08 – 06:12: shot of graphs on screen, GC continues “the other fish we’ve identified are trout” – shot of M removing another silhouette sticker to reveal fish labelled trout

M) – "excellent, trout"

GC) –"and third fish we though was cod" – M removes sticker to reveal fish labelled cod

M0 – "cod)

GC) – "and the fourth fish was haddock"- sticker removed revealed haddock, M laughs – "ok, ok"

M) – "it's a very tense game, there's no massive prize sadly at the end of this" – GC laughs – " I feel as if there should be, two to go"

GC) – "OK now with the other two we had difficulties with them in terms of the quality of the sequence"

M) – "ok"

GC) – "er so one them we actually thought was not a very good quality sequence, visually when we took it from the pie it looked to us like it could be catfish, Vietnamese catfish, or otherwise known as river cobbler, but we had it sequenced alongside all of our other samples and it came back as a bacterium, so it can actually of course indicate poorly stored fish, when we think about Vietnam it's a long distance away and the likelihood is of course that parts of that, or periods of that the fish may have been stored above freezing for quite some time"

06:13 – 07:15: "well let's just see if you're correct, and it is indeed" – removes sticker – "river cobbler and of course this is at the heart of the scandal" – close up of picture of fish labelled river cobbler – "with fish and chip shops wasn't it?"

GC) – "yup, yes indeed, no river cobbler has been a major culprit actually in substitution across the world. Once it's been stored for a period of time the white flesh can look something like cod or and of course it is I think quite readily substituted"

M) –“and in our red herring pie, this was the fish that we wondered whether or not you would spot”

GC) –“it was quite evident to us, or very likely to be catfish, so something that we could readily recognise” – shot of computer screen with database map homepage on it, shot of DNA text in a file, M) voiceover –“the identity of the last species wasn’t clear from the first analysis, but a routine” – shot of results page on computer screen – “second test did confirm the result, cut back to M) and GC, GC) – “the quality of the sequence is not up to our usual standard but we do have pretty high certainty that it was monk fish” – cut to shot of M) removing silhouette sticker – “based on resequencing it more than once” – picture of monkfish is revealed – “a retest also confirmed the river cobbler” – shot of fish on board - “complete with bacterial contamination giving Dr Carvallo an impressive six out of six”

07:16 – 08:12: cut back to M) and GC in lab, GC) – “we see all these fish on the board here that are clearly identifiable” – shot of pictures of fish on board – “very easy to distinguish,” – cut back to GC and M - “but once the fish have been processed and filleted and,”- shot of board – “often prepared in a variety of ways, it becomes increasingly difficult” – cut back to M and GC) - “to be absolutely certain what is on the label is what’s inside the packet” – cut to neon sign of fish and chips brought into focus, M) voiceover – “technology like this doesn’t just benefit consumers” – shot of boats in harbour – “it’s also helping to tackle illegal fishing and protect vulnerable fish stocks” – shot of boat in estuary then seagull flying over it – “because professor Carvalho has pioneered a system that can even pinpoint where certain species were caught”- cut to M) walking along pier, piece to camera – “from this year all fish and fish products that is eaten within the EU will have to be labelled not only with the species but whether its wild or farmed and it will have to state exactly where it’s been caught, and with these advances in fish forensics it’s going to get harder and harder for the fraudsters to slip through the net.”

08:13 – 09:12: cut to shot of onions being cooked on griddle, then burger being placed in bun, shot of L) taking burger from market stall holder, turns to camera – "cheers, So that's good news for fish eaters but you do have to wonder why this technology wasn't used to avoid the horsemeat scandal but the thing is fish testing is very different to meat testing, in meat testing your looking specifically for cross contamination with other farmyard meats, so you're looking for the DNA of lamb and beef and pork and poultry, but not for the DNA of horse, it was only after a tip off that they went looking for it and unfortunately found it" – cut to time lapse shot from inside trolley, normal speed shot of man taking something out of supermarket chiller , man walking along chiller aisle, J) voiceover – "but food fakery is only one of the things that worries consumers" – shot of man reading ingredients on tub of food, cut to vox pop with middle aged man – "just look at the produce you know and if I think it looks good I will buy it" – cut to two women used in vox pop at start of programme – "spraying your food with this or that to make it keep its shine and everything else so, so yeah I'm sure that there's all sorts of unsavoury practises going on" – cut to close up of packaged salad, words 'packaged in a protective atmosphere' in focus, J) voiceover – "one of the tricks of the trade is to package foods in strange atmospheres so what's that all about?"

09:13 – 10:25: cut to shot of J) workshop bench, places pack of steak on it, begins piece to camera – "meat is actually packaged quite often in an atmosphere very rich in oxygen, far more oxygen than we're used to breathing" – close up of J piercing small hole in lid of packet, then lighting splint in candle flame, - "blow this out" – blows out lighted splint, then inserts glowing splint into meat packet, it relights quite fiercely – "it sort of leaps into flame very easily" – takes it out of packet and blows it out, then reinserts it and it relights again – "whooah, look at that. Now the reason for this is cosmetics" – shot of two bits of steaks in packs on bench, J voiceover – "just as blood turns a brighter red with oxygen, so does muscle" – cut back to J behind bench, piece to camera – "and so by flooding it with oxygen the kind of muscle in there gets to look much redder than it would normally" – cut to earlier shot of 2 steaks in packs – "and we think, that's the one to buy" – shots of plastic boxes of salad, J voiceover – "but pre-packaged salads can be the total opposite. They're packed in atmosphere with very little oxygen" – cut to J lighting splint in candle, piece to camera –" I'll show you what I mean, light this and I plunge it into a little basket of salad" – close up of splint going into salad box, splint goes out – "it will not stay light" – relights splint, puts it back into salad box, goes out again – "and that's because there's no oxygen in there really, so the things that would normally cause the food to rot and decay, cant thrive so the food stays fresh a lot longer."

10:26 – 11:35: cut to time lapse trolley shot, fruit being placed into trolley, J voiceover - "we all want to buy fruit and veg at the peak of perfection but there's a fine balance between ripe and rotten and getting that right is all about" – time lapse shot of new shoots emerging from leafy ground – "another gas, ethylene" – time-lapse shots of flowers blooming – "this the same gas that plants use to make flowers open" – time lapse shot of forest turning from green to orange – "leaves change colour and drop off in the autumn" – cut back to J in workshop, behind some apparatus, undoing bottle, voiceover – "because ethylene is regarded as dangerous it's difficult to get, so I'm going to make my own" – shot of J soaking cotton wool with methylated spirits, shot of cotton wool in horizontal glass tube with white powder and J placing rubber bung in the end – "starting with ethanol" – shot of blow torch, J putting on safety goggles, shot of powder in tube being heated – "I need to heat the ethanol in order to vaporise it" – shot of J inserting tube into upturned plastic bottle, shot of J heating powder in tube – "and break it down into water and ethylene gas" – shot of water bottle with tube in submerged in large vat of water, close up of bottle with tube in with gas bubbling into it, shot of J syringing out contents of bottle, piece to camera – "what I've collected here should now be pure ethylene gas" – shot of J taking sniff of syringe contents, reacts by flinching away and pulling a face – "it certainly smells pretty fruity" shot of J holding syringe near blow torch flame, releases syringe end and gas ignites very easily – "and its phenomenally flammable" – shot of green bananas – "its harmless to humans and to fruit it's a ripening hormone" – shot of J putting banana in jar – "I'm adding a quick blast of ethylene here, just like they do to kick-start ripening before bananas are delivered to the shops" – shot of J screwing on lid of jar then injecting syringe content through valve in top, close up of banana in jar

11:36 – 12:40: shot of banana in jar next to banana not in jar, counter in the corner with 'day 1' written in it, J voiceover – "from then on it produces its own" – now 'day 2' – "and continues the process," - day 3, day 4 – "so the timing is critical" – banana in jar is becoming clearly more ripe than banana outside of jar, day 5 – " or your banana will end up too ripe too soon" – shot of just banana in jar, becoming overripe and brown and then almost rotten, cut to shot of J walking alongside factory towards entrance, sign above reads 'worldwide fruit', voiceover – "for fruit distributors like this one, getting ethylene levels right" – shot of inside of factory with workers and machinery – "is crucial" – cut to J inside factory in white coat and hair net, standing next to clean hat dispenser, piece to camera – "working with it as opposed to riling against it has enabled suppliers to time their fruit and veg deliveries to near perfection" – shot of man driving a forklift through a warehouse, J voiceover – "apples are relatively easy" – shot of workers placing apples on conveyor belt – "to store, cold storage does most of the job" – shot of worker sorting apples on belt – "but they're kept separately so" – close up of apples on belt – "their ethylene production doesn't affect more sensitive fruits" – shot of ceiling vents in large room with lots of boxes (presumably of fruit) in it, shot of forklift removing boxes from high shelfs with lots of boxes above it, music klaxons song which began with first shot of forklift becomes more prominent, steady prominent rhythm links to methodical work of factory staff and machines, shots of workers packing pears on conveyor belt – "but pears we want to be much juicier, they are taken right to brink of ripeness before packing but then" – shot of worker putting small white squares into empty pear packages – "held there as long as possible by these little white patches" – shot from different perspective of worker putting patches in packages on conveyor belt and further down the line other workers filling packs with pears – "ethylene absorbers which mop up the gas inside the packet."

12:41 – 13:42: cut to J on factory floor in white coat and helmet, talking to another man, asks him – "so when I buy them should I keep them in the packet you delivered them, with their little ethylene absorption" – close up of patch in J's hand – "patch, and then they'll last for longer" – shot of other man in coat and helmet, replies – "that's exactly what you should do really" – shots of packaged and sealed pairs on conveyor belt, man continues – "just before you want to eat them, about an hour or so, take them out of the cold fridge, put them on the side, temperature will change to room temperature" – label appears on screen reads 'Tony Haring, Technical Manager of World Wide fruit', - "and then you'll get a very enjoyable experience with the pear yeah" – shot of J and TH walking past pears near conveyor belt, J voiceover – "for the perfect avocado experience" – shot of TH and J entering a different room, large sliding door rising and revealing them, shot from inside the room before they enter – "the whole process gets much more complicated" – shots of avocados on conveyor belt with light flashing over them, J begins – "this machine actually checks out every single" – cut to Jem standing in front of machine whose light can be seen flashing rapidly in background – "avocado, er their kind of tapped and listened to, to find out what they're like inside" – shot of this happening in machine, - "then they are photographed from many angles to find out what they are like on the outside" – shot of light flashing over avocadoes –" and then form that a computer deduces – "cut back to J) – "exactly what state each ones in and whether it's supposed to be eaten in two days or whether it would be perfect in a week or" – shot of avocadoes leaving machine on conveyor belt –"ten days" voiceover – "avocadoes don't ripen at all until they're picked" – shot of avocadoes on tree being picked – "but from then on it's a tricky balancing act" – shot of avocadoes on conveyor belt – "to store them on mass but also ensure they all get ready together"

13:43 – 14:50: shot of large sliding door being opened to reveal stacks of fruit boxes, J voiceover – "it's a combination of temperature control" – shot of J and

TH standing in front of boxes, then close up of patches in TH's hand – "and these large ethylene absorption pads" – TH begins to speak to J – "and basically what this is doing is absorbing the ethylene from the ones that are ripening quicker than the others so it's basically shutting them ones down in terms of their speed of maturity, allowing the ones that are less mature to catch up and so hopefully you'll end up with a much more even sample " – blurred shot of fruit on conveyor belt brought into focus, J voiceover – "visiting this packing factory has made me realise that different kinds of fruit" – shots workers removing fruit from boxes on conveyor belts – "are all speaking the same language, and it's called ethylene" – wider shot of factory floor with workers, forklift, machinery, cut to J in room with avocado boxes, piece to camera – "and these avocadoes have to be kept separate from the apples and pears to stop them talking to each other to stop one releasing ethylene and telling the others to start ripening and start changing rapidly, and these things here there almost like kind of mufflers" – holds up ethylene absorption patches – "they absorb the ethylene to stop them communicating with each other" – shot of avocado room door closing, J continues – "it's really about understanding the biology of what we eat" -, cut to J in different room with boxes, to camera – "in order to keep it fresher for longer so we can get more out of it and hopefully produce less waste" – J takes bite out of apple – "which er has to be a good thing"- walks off camera

14:51- 15:55: shot of slices of beef in small glasses with gravy being poured over them, twitter tag in corner, L) voiceover – "still to come tonight Maggie discovers how scientists" – shot of Maggie in white coat and hair net smell brown substance on stick – "can fool us with flavours" – cut to time lapse trolley shot – "but first I'm taking a look at the additives" – shot of Liz removing food from chiller cabinet –" that seem to be in so much of our food" – close up of ingredient list on tub of food, L) piece to camera –"if you take a look at the list of ingredients in a lot of the stuff that you buy, chances are there a whole bunch of things that you've never even heard of so what are they and why do they feature so heavily in foods like these?" – holds up to ready prepared food items, cut to Liz asking shoppers outside supermarket about the food in their bags, L0 – “can I rummage around and just have a look at what you might have?”

Female shopper – “yes certainly”

L) – “let me see these, listen to this right, flavourings colours, e104, e122, e110, any idea what they are and what they’re for?”

FS) – “No” – cut to different woman giving vox pop – “when you read the label you do need to be sort of like in the pharmacy industry to understand all the chemicals and other bits and pieces, cut to Liz talking to male shopper, reading ingredients on loaf of bread, L) – “E471, e 920, emulsifiers and calcium propyonate any ideas?”

MS) – “no” – cut to L) with different male shopper reading ingredient on pack of chicken legs L) – “dextrose, do you know what dextrose is?

MS”) – “No”

L) –“do you know what stabiliser E451?”

MS2) – “no”

L) – “why would you want to out stabiliser in chicken what would it be for, do you know?”

MS2) – “er again haven’t the faintest idea” –

15:55 – 16:54: shot of Liz walking past pond with 2 shopping bags, L) voiceover – “the truth is additives go hand in hand” – shot of variety of processed foods being taken out of bag and placed table, sped up – “with processed food, which is pretty much everything that isn’t a raw ingredient” – shots of products on table, cut to L) in kitchen behind worktop with ingredients on it - “a really good example of how additives can be fairly obvious in foods is salad dressing. Now first up if I made my own at home, all I’m going to put in is you know a bit of olive oil” – shot of L pouring olive oil into jar – "and vinegar" – shot of L picking up vinegar, then shot of L spooning mustard out of pot – "and then I always bung in a bit of mustard" – puts mustard in jar – "and then just give it a good stir" – stirs mixture – "and that does the job" – close up of jar with contents mixed – "no additives needed" – cut back to L) – "no oil and vinegar don't mix, but the mustard in my dressing a) tastes really good but b) it acts as an emulsifier and what that means is there's a chemical in the mustard that bridges the gap between oil molecules" – demonstrates this with hands in fist representing molecules – "and vinegar molecules which essentially repel each other, and essentially makes" - close up of jar with contents separating out – "my dressing into an emulsion, but that doesn't last very long"

16:55 – 18:17: shot of Liz looking at jar, spoken to camera – "now as my salad dressing settles, you can see all the different components" – shot of jar with mixture more separated – "the oil and the vinegar are separating and also all the mustard seeds have settled to the bottom" – cut back to L) – "but if I show you an equivalent salad dressing that comes from a shop" – holds up store bough dressing in bottles –"there's no separation whatsoever and all the seeds"- close on bottle with emulsified dressing inside it – " are suspended throughout, it looks very different" – holds up jar and bottle to camera to compare and they do appear different, L) voiceover – "but I need just one secret ingredient to get my DIY dressing bottle ready" – buts jar and bottle down, then to camera – "now this is E415" – picks up bowl of white powder – "or xanthum gum and it's a very popular additive its used in hundreds of salad dressings and sauces, and it comes from this little bacteria, xanthumonous" – hold up petri dish with bacteria on it – "campestres, and it's what causes the black spots on broccoli and cabbage and it uses this gum like substance that it secretes to attach to the leaves of the vegetables, but when that gum is dried out" – shot of powder in bowl - "it looks like this" – L) takes a pinch and sprinkles it into her dressing – "and if I add a little bit to my dressing, stir" – she stirs dressing – "look at that already" – dressing appears to thicken – "I can notice a bit of a difference" – L) voiceover – "the gum further emulsifies the dressing but also surrounds the molecules of oil and vinegar" – blurred shot of Liz mixing from slightly further away during voiceover – " stabilising the mixture so that the oil and vinegar" – close up of now emulsified salad dressing – "can't separate back out"

18:17 – 19:14: shot of L) holding up jar, piece to camera – "but xanthum is also a thickener , it's also made my dressing a lot more viscous and that means that all the mustard seeds are now sort of permanently suspended in my dressing and suddenly" – picks up store bought dressing – "these two don't look that dissimilar anymore" – holds both up to camera and they do resemble each other more in texture if not colour, shot of L0 adding water to jar, voiceover – "because it's so thick I can even water it down" – mixes in water – "which not only makes it cheaper to produce" - to camera, holding up jar – "it also gives you a fraction of the calories per teaspoon" – shot of dressing being poured over salad, voiceover – "xanthum is just one of hundreds of additives used in our food" – cut to shot of L) now with man in glasses – "chemistry professor Andre Seller is going to show me some of the most commonly used additives" – fast cycle through of shots of different powders in bowls on table, then liquids with labels in front of them- "in mass produced foods, like this Victoria sponge cake" – shot of cake on plate, close up of cake, L) begins asking –"Ok so what are the challenges you know do you have to face when making cakes on a mass scale?"

19:15 – 20:36: shot of L) and AS) behind table with various powders in bowls on it, AS replies –"one of the things you have to worry about is shelf life, now we know" – close up of top of cake – "that if we leave a cake lying around its going to dry out, so for example there are things called humectants" – cut back to AS – "these are really edible moisturisers and a good example is" - AS picks up bowl of clear viscous solution, close up of it – "would be glucose syrup" – L pokes at syrup, sticks her finger in it, L) voiceover – "humectants like" – L picks up and stretches thick syrup – "glucose and glycerine keep the cake moist but also" – shot of ingredients on table in conical flaks, labels, one reads 'potassium sorbate' other 'humectant (vegetable glycerine)' – "stop mould growing" – AS picks up flask of humectant, swirls it around to shows it viscosity –"and extend shelf life. But mass produced foods" –close up of cake – "also need to be consistent" – cut back to L an AS, AS begins – "If you think about when you bake at home you know one cake will always be slightly different from the next and a big producer cannot afford that every single cake must come out completely identical so what they really need is control and this is where emulsifiers" – close us shot of label, reads 'cake gel emulsifier' – "come in, what you get is this slightly" – pan up to what is in bowl, white paste-like substance looks like lard or – "sort of gloopy" – cut to shot of AS pickling up bowl and showing it to Liz – "soapy material" – rubs some on his fingers, Liz does the same, L) – "it feels a bit like Vaseline as well"

AS) – "it certainly feels odd, and what this is designed to do is kind of the same thing that the egg does" – shot of eggs in bowl – "when you bake a cake" – back up to AS – "and that is to control the bubbles within, within your cake

L) – "but much more than the eggs do?"

AS) –"and it provides much finer control" – close up of cake – "much more careful control in fact what it really does is to" – cut back to AS – "ensure that we will get a consistent structure to the bubbles inside our cake"

20:37 – 21:51: shots of powders and liquids in bowels and bottles on tables, shot of L walking away from front door of house, piece to camera – "so at additives definitely serve a very useful purpose in the food industry, and when it comes to safety of course questions will be raised every now and again, but every additive that features in our food has been rigorously tested" – shot of someone taking packaged food of supermarket shelf, L voiceover – "and indeed the E in very E number simply means that the additive has passed European" – close up of ingredients list – " safety testing" – cut to shots of shoppers in supermarket, muse knights of Cydonia as soundtrack, cut to time lapse trolley shot M) voiceover – "thanks to the additives in processed foods more often than not what your tasting" – close up of pot noodle lid with beef and tomato flavour prominent – "isn't quite what" – close up of roast chicken and herb flavoured something – "you're eating" – close up of beef flavour rice, cut to shot of food bioscience sign on building – "I've come to the university of reading" – shot of M walking into building –"to find out how scientists manage to give plain food gourmet flavour" – cut to shot of M) with another woman both in white coats and hair nets, in front to hob with frying pan on it and steak in pack next to it, other woman asks – "so Maggie how do you like your steak?"

M) –"I'm a medium rare kind of person"

OW) –"oh excellent I'm glad to hear it cos I like – " – M) voiceover drowns out reply of OW, M) –"today Dr Jane Parker is cooking" – shot of steak being put into pan – "up a prime pan fried steak to show me what makes it so deliciously meaty" – back to M talking to JP, M) asks – "if you are a meat eater there is nothing like that moment when the steak goes in the pan and all of the wonderful - "

JP) – "you start to get those aromas coming off already, it doesn't take very 'til you get that aroma coming off"

M) –"yeah"

JP) - "and what's happening on the other side is its starting to go brown"

21:51 – 22:58: close up of steak cooking in pan, jazzy piano music, M) voiceover – "the basic flavour of food comes from its taste, bitter, sweet, sour, salty and if its meat umami, but far more important for flavour is the foods aroma" – steak is flipped in pan, back to M and JP talking, JP) – "so yeah you can stick your nose over it and you can smell that aroma coming off it, ooh", M) voiceover –"so Jane's first step is to identify the signature components of gourmet steak" – shot of JP placing bits of steak in conical flask – "aroma. She puts the pieces" – close up of pieces of steak in flask – "the pieces of steak into a gas chromatograph which"- shot of JP putting flask into large machine – "collects the aroma, before separating out and measuring" – close up of part of machine, then JP pressing buttons on touch screen – "every component displaying the results on a graph" – shot graph on a screen, cut to M and JP talking in front of screen with graph on, JP) – "each peak is a single component that's come from the aroma that's come off the steak" – shot of graph –

M) – "There's probably at least a hundred" – cut back to JP and M in front of screen

JP) – "I'd say a couple of hundred easily, but you could go up to six hundred if you looked at absolutely everything that was there, there's one somewhere here" – shot of graph – "we've found, people describe it as rotting" – cut back to in front of screen – "drains rotting vegetables, rotten eggs, it's really got a nasty aroma but its required you need to have it there to give you that nice fried steak aroma"

22:58 – 24:03: shot of different graph with hand pointing out something on it M) asks – "where do you start when you trying to recreate something which can almost con our taste buds into thinking oooh delicious meaty flavour"

JP) – "well the first thing you need to do is work out which of the flavours peaks are important, which compounds are actually giving you the aromas that you need" – cut to shot of steak being fried in pan, M) voiceover – "but giving a delicious flavour to processed food is more complicated than just adding those aroma compounds, in something like a steak there are specific natural chemicals which react together during cooking, each combination generating a different aroma, those precursor chemicals build up in meat as it matures" – shot of steak being chopped into small bits – "producing an even stronger reaction in the pan, and that's what gives a quality steak its rich gourmet aroma. It's called the Mayard reaction and it gives all cooked foods"- shot of graph – "their signature aroma" – cut back to M) and JP, M) begins – "this is a real art isn't it?

JP) – "oh it is, you need the science, you need the chemistry to understand how the flavours are generated, but there's an awful lot of art in it is as well, you need to have a good nose, to be able to create erm an aroma that's convincing

24:04 – 25:07: shot of graph, M) voiceover – "one man who can do that is Dr" – cut to shot of white-coated man sniffing at brown substance on stick – "David Baines, he's worked out which of the precursor chemicals in a steak are responsible" – shot of Db handing M a bottle to sniff - "for those signature aroma peaks" – M) sniffs bottle - "to reproduce that natural flavour he just mixes those chemicals" – close up of tub with label, reads 'Ribose' – "and cooks them, first a dash of natural ribose powder" – close shot of white powder being put into a jar, cut to M and DB behind a bench with a pressure cook and a number of plastic bottles, DB begins – "this is the key sugar in meat" – tabs plastic bottle contents into jar, M) voiceover continues, close up of plastic bottle with label, reads 'cysteine' – "next some cysteine" – cut back to M and DB, DB) – "this is the power house, this produces hydrogen sulphide" – taps bottle contents into glass jar, M) voiceover, close up of plastic bottle, label 'glutamic acid' –"then a pinch of glutamic acid, a natural monosodium glutamate, or MSG" - close up of powder being poured in jar, then close up bottle with label, reads, ribonucleotides – "the some ribonucleotides" – cut to DB and M, DB) – "and the ribonucleotides and the glutamate are what give us umami" – taping bottle into jar

M) – "and that's the fifth-

DB) – "the fifth taste, yes, sweet sour, bitter salty umami – close up of bottle with label, 'yeast extract', M) voiceover – "a dollop of yeast extract" – close up jar with powders in – "adds body" – cut back to M and DB, DB) – "and er it won't work without the water" – adds water and shakes jar, M) voiceover – "at this stage the mixture has very little flavour, but that will all change after half an hour in a pressure cooker"

25:08 – 26:20: shot of DB placing jar in pressure cooker, M) voiceover – "now it may seem very artificial, but this lab flavour, could be safer than the real thing", cut back to M and DB in conversation, DB) – "when you cook a piece of meat you do get some substances formed that have been linked to cancer" – shot of plastic bottles which had chemicals in – "they're formed from a precursor called creatine, I don't use creatine, so they're not going to be formed" – shot of DB undo valve on pressure cooker and steam escaping – "as you do with a normal pressure cooker", M) voiceover – "finally it's time to check the results" – DB removes lid and then takes jar from cooker, M) – "I can smell it already"

DB) –"and here we have it, you see the colour formation taken place" – undoes lid and offer it to M to smell

M) – "ooh (laughs) I'm not sure whether that's pleasant or not" – close up of brown liquid in jar, voiceover M0 –"that has to be the beefiest beef I have ever smelt" – shot of M and DB smelling small amount of liquid on sticks, shot of liquid in jar, shot of M and DB behind desk with bits of beef being rolled up, M voiceover – "now for the test, we've taken some bland" – close up of beef on board – "pre-sliced beef, with none of the flavour of a prime pan fried" – rolls of beef put into glasses using toothpicks with red and blue flags on the end – "steak, and we're going to see if a few drops of David's potion can give it a flavour" – shot of gravy being poured onto beef in glasses – "makeover. Add gravy to each sample but only those with a blue flag get gravy containing the flavouring"

26:21 – 27:24: cut to outdoor shot of M) with tray of glasses of beef with flags in, piece to camera – "well they say the proof of the pudding is in the eating, so let's put it to the test" – walks off camera, approaches some students at a table – "excuse me, do you have a moment to help us with a taste test" – passes out glasses of meat, voiceover- "our guinea pigs are students from the university of reading" – shots of students eating meat – "I asked them which tastes meatier, red or blue" – shot of meat being handed out to different group of students, shot of one female student eating bit of meat, shot of group of students, to female one male, first female student replies – "red I think" – second female student replies – "I think blue not red" – male students agrees, cut to shot of M asking Asian female student – "tell me which one is the meatiest?" – shot of AFS eating blue meat, then red meat, replies "oh, definitely this one" points at blue – "blue one"

M) – "Really" – cut to shot of different female student eating meat says, "the first one was more meaty"

M) – "So the first one much meatier" – shot of hand picking up red flag meat, cut to male student with one in each hand, says "the blue ones really strong"

M) – "yeah"

MS2) – "yeah like super strong, whereas the red ones quite watery , not much taste" – cut to shot of different male student eating meat, then another male student eating, M) voiceover begins – "80% of the people we asked thought our" – shot of female student eating meat – "enhanced beef was tastier" – female student says – "the blue one"

M0 – "the blue one, and how did that taste in your mouth compared to the read one?"

FS) – "it's just got more flavour"

M) – "yeah" – shot of M walking with close up on tray M) voiceover – "in our experiment we were only using flavourings to make bland meat taste meatier" – shot of female student eating a sausage roll –"but they can also help us in the" – shot of shopper carrying shopping bags – "search to find new sustainable" – shot of shop front, then food in canteen serving trays –"sources of protein"

27:24 – 28:16: shot of fishing net being hauled onto boat full of fish, shot of herd of cattle – "whether it's from meat grown" – shot of small blob of meat on petri dish – "in a test tube" – shot of insect, then close up of insect –

"insects, or micro-protein" – shot of brown cubes on conveyor belt (assumed to be micro-protein) – "lab made flavourings" – shot of sauce pan being emptied of brown mince looking substance (assumed to be Quorn) – "could transform alternative sources of protein" – shot of Quorn being stirred into sauce, then shot of sausage plait cut in half – "into something much more pleasing to the palate" – cut to J and L walking through market, J piece to camera –"one things for sure, food technology involves a broad and fascinating range of science and it is to a great extent driven by the need to keep costs down, reduce waste and meet customer demand"

L) – "absolutely and the important thing is, is to arm yourself with as much information as possible so you can decide" – web address appears on screen – "what you want to eat and what you don't, we'll see you next time, bye"

J) – "good bye" – website screen shot appears, J) voiceover – "visit bbc.co.uk for another wad of my web exclusives and you can follow the links to the open university for more information on food importing and the global supply chain" – credits roll

Episode Ends

APPENDIX 2

Information Sheet and Informed Consent Form

This appendix provides sample copies of the information sheet and informed consent form that I provided participants before interview. All participants were asked to sign the informed consent form after reading the information sheet, to indicate their willingness to participate in the interview and their understanding of to what use the data generated in the interview would be put. All participants were happy with this arrangement and agreed to sign the form after reading the information sheet.

Information Sheet for Interviewees

Introduction

My name is Will Mason-Wilkes. I am a PhD researcher from the School of Social Sciences at Cardiff University. I am working out of the Centre for the Study of Knowledge, Expertise and Science (KES).

The Purpose of the Project

The focus of my project is on the differing ways science is portrayed in media of mass communication. I am particularly interested in the differing styles of communication employed in non-fiction programmes about science. I intend to investigate the ways in which the creative process of programme making impacts upon the finished programmes which are broadcast to mass audiences. You have been identified as a relevant person to interview as you have experiences of being involved with the creative process on mass media science programmes.

How will the research be conducted?

The research will be conducted in the form of a face-to-face interview between you and myself. This interview will take place at a location convenient to yourself. This interview will last around an hour and will be audio-recorded.

Possible disadvantages of participating

There are no known risks or disadvantages to your participation, as I will endeavour to protect your identity. Unless you explicitly state otherwise your details will remain anonymous in the final PhD document which is produced for assessment. If you so request, before the PhD is finalised you will be sent a copy of any transcript which is produced from the interview you take part in to allow you to ensure that you have not been misrepresented.

Possible benefits of taking part

You will have the opportunity to share your knowledge of the creative process of science television making. This will help to further the understanding of the academic study of science communication. This in turn may help future science communicators in their communicative endeavours as well as benefiting more general public understandings of science.

What happens when the research is over?

The information collected in the interview will be used in my PhD thesis. This thesis will be examined by faculty members both internal and external to Cardiff University. Data from this thesis could also be used in subsequent academic publications in journals and at academic conferences.

Please see overleaf for further information

Do I have to take part in this research?

You are under no obligation to participate in this research. You can withdraw your participation at any time during the interview and anytime thereafter up until six months before the thesis is submitted (September 2016). You may withdraw your participation without providing a reason for doing so and no adverse consequences will arise if you do withdraw. If you choose to withdraw after your interview you must contact me indicating your withdrawal in order for your data to be securely deleted. You will not be able to withdraw your participation after March 2016 due to the writing-up requirements of the researcher.

Problems or Concerns

If you wish to raise a complaint or concern regarding your treatment at any time during the course of the study then this will be addressed. Please do not hesitate to contact myself (07930505909, mason-wilkesWJ@cardiff.ac.uk) or the Research Supervisors (details provided below) with any concerns you may have.

Confidentiality

Unless you explicitly state otherwise, all the information you provide will be anonymised in order for you to remain confidential. No one reading the final PhD document or any subsequent publications will be able to readily identify you unless you explicitly state that your real name and information can be used.

During the course of the study only I will have access to the recorded interview data which will be stored on secure, password protected servers at Cardiff University. In line with Cardiff University Policy, this data will be stored on these secure servers for no less than 5 years or at least 2 years following the publication of the thesis.

Researcher Contact Details

Principal Researcher	Supervisors
Will Mason-Wilkes School of Social Sciences Cardiff University Cardiff Office: 1-3 Museum Place, CF10 3BD Email: mason-wilkeswj@cardiff.ac.uk Tel: 07930505909	**Professor Harry Collins:** CollinsHM@cardiff.ac.uk **Dr. Robert Evans:** EvansRJ1@cardiff.ac.uk

Who is funding the Research?

The research is funded by the Economic and Social Research Council (ESRC)

Who has reviewed the project?

The project has been approved by Cardiff University School of Social Sciences School Research Ethics Committee (SREC)

Thank you for taking the time to read this information sheet. If you have any further questions please do not hesitate to ask

Informed Consent Form

I……………………………………………………………………………………………agree to participate in the PhD Research of Will Mason-Wilkes

I have read and understood the purpose of the study as outlined in the information sheet provided alongside this informed consent form.

My participation in this study is entirely voluntary

I give permission for my interview with Will Mason-Wilkes to be digitally recorded using a digital audio recorder

I understand when and how I can withdraw my participation from this the study and that there will be no adverse consequences if I do so.

I understand that unless I explicitly state otherwise, my identity will be protected through the anonymisation of the interview data collected when the data is written up in the final PhD thesis and any publications which are later produced from it.

*(Please tick **ONLY ONE** of the following)*

I would like my identity to be anonymised during the writing up process ☐

I would like my real identity to be used in the writing up process ☐

I understand that extracts from my interviews may be used in the final PhD thesis and any subsequent publications which are produced from it.

Please tick the following box if you would like a copy of any transcript produced from this interview to be sent to you before publication ☐

Participant:

Signed………………………………………………………………………….. Date:……………………...........

Researcher

Signed…………………………………………………………………………. Date:……………………………

APPENDIX 3

This appendix provides specific information on the subjects pursued, and educational level achieved, by my respondents.

Respondents Educational Level

12 of my interviewees self-identified as having some form of scientific education. 3 of these interviewees were academic scientists employed by university science departments (and were all science TV presenters). Of the behind-camera interviewees, 1 had held a post-doctoral position in a biochemistry lab for 3 years before leaving to work in the media. 4 of my respondents hold PhD's, 3 of which were in hard science subjects (1 in zoology, 2 in physical geography). 5 of my interviewees hold undergraduate degrees in scientific subjects (natural sciences, engineering, physiology and pharmacology, zoology, geography) The interviewee who had studied geography at undergraduate level had gone on to study for a PhD in Human Geography.

2 of my interviewees were borderline cases. One studied human geography and the other psychology – both at undergraduate level. Though these subjects could be classified as scientific both respondents stressed that they felt they're studies were not scientific in nature

> Producer-Director D: "I did human geography so my dissertation was on the affordability of mosquito nets in Malawi, I mean there was absolutely no science as far as I can remember in my geography degree, I mean I'm sure there was in the first year when you have to do a refresher course on volcanoes and they give you some numbers and things like that and something on statistics or whatever but I studiously avoided anything that has numbers or laboratories in it"

> Senior Executive J: "I did psychology at university, I got terrible a-level results and staggered into a low-grade

> university college in London, and got a very iffy degree in psychology which was at that time trying to make up its mind whether indeed it was a science or not, most of our discussions were around that as far as I could see"

6 of my interviewees self-identified as having no scientific education at all. Of these 6, 2 interviewees had university or equivalent training or education in film-making, 1 studied for an undergraduate degree in English, one for an undergraduate degree in in Politics and Philosophy and one for an undergraduate degree in Politics with Chinese. The other respondent disclosed that that they did not have a science degree, but did not tell me whether they had a degree of any kind.

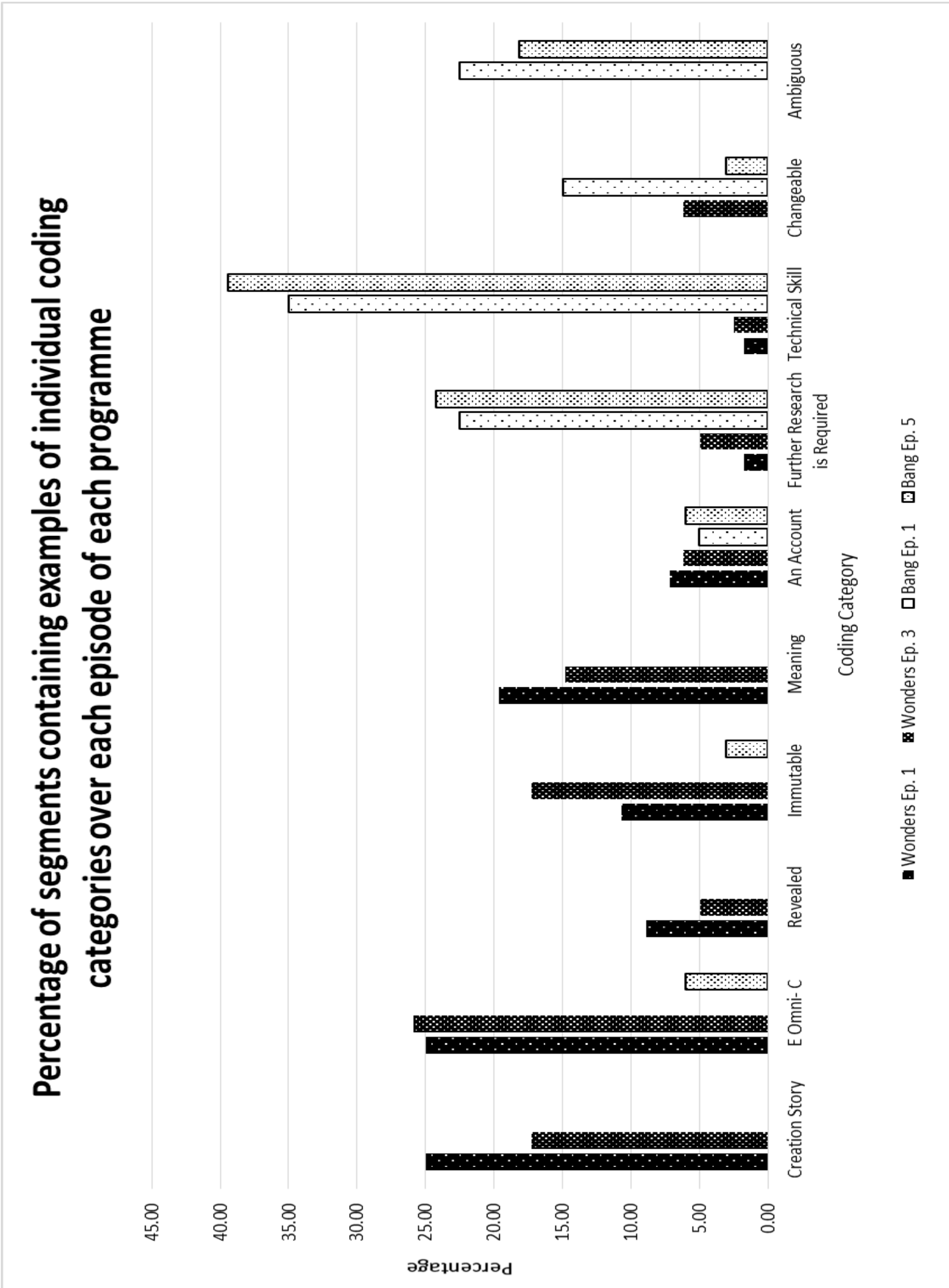
2 of my interviewees had no direct experience of working in science television production. One was involved in science radio and the other in natural history television production. The interview with the science radio producer was the first I conducted. This was used in part to pilot the interview schedule I had constructed. The interview was also very convenient as the interviewee was in Cardiff so I was able to pilot my interview schedule and practise my interview technique. The interview data from the interview with the natural history producer was used to contextualise accounts and corroborate some claims provided by the interviewees who had experience of science television production. No direct quotations from these interviewees appear in the main body of the thesis. A summary of the above is presented in the following table.

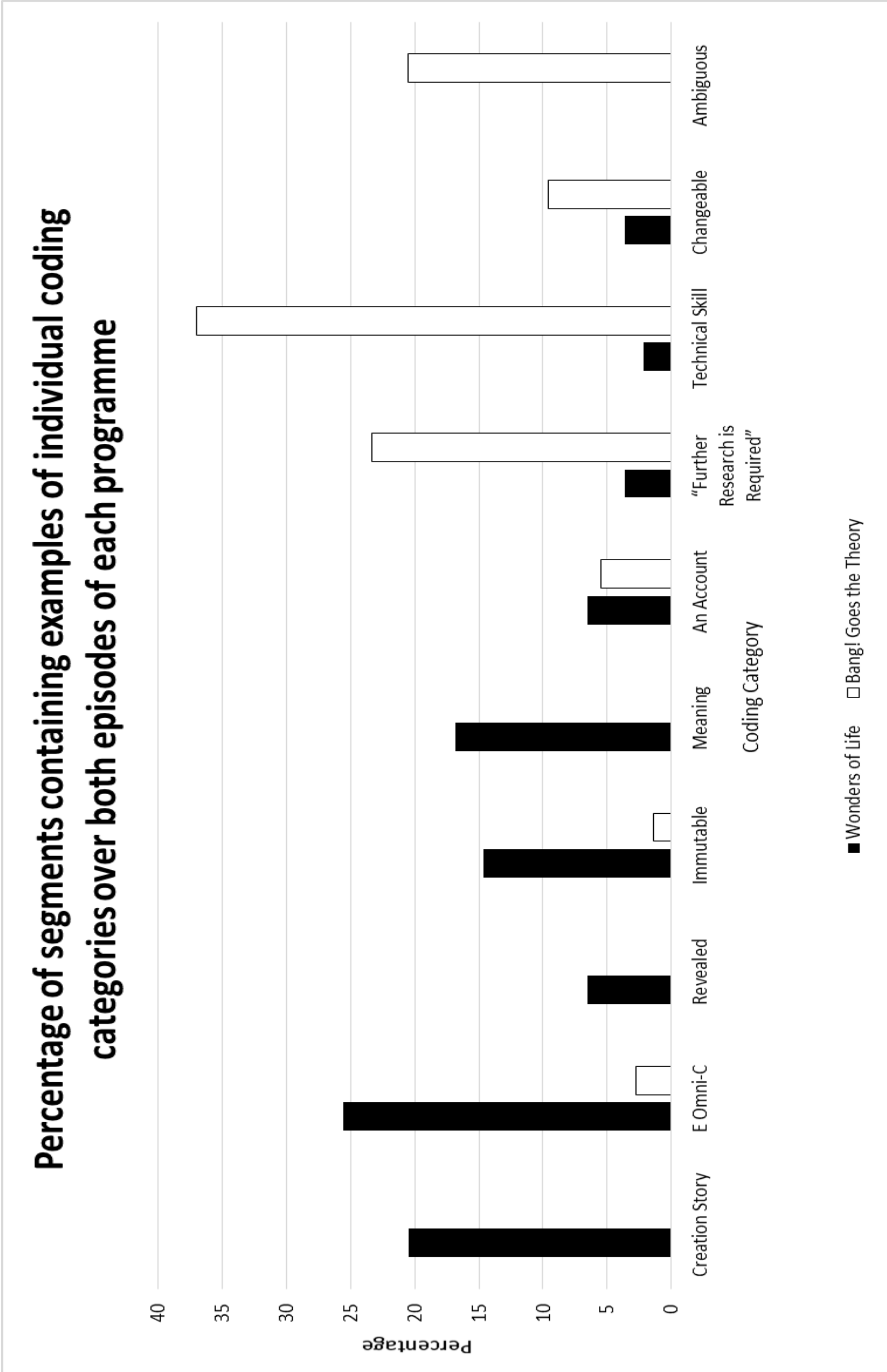
INTERVIEWEE	ACADEMIC SUBJECT BACKGROUND			
	Undergraduate	Masters	PhD	Post-Doc onwards
A*	Zoology			
B (Producer-Director)	No degree specified			
C (Producer-Director/Series Producer)	Zoology		Zoology (butterflies)	
D (Producer-Director)	Human Geography			
E (Executive Producer)	Geography		Geography (Human Geography)	

F (Executive Producer)	Geology and Environmental Science		Geology	
G (Producer-Director)	Geology		Geology (volcanoes)	
H (Executive Producer)	Natural Sciences (Primatology)			
I (Senior Executive)	Art & Film-making			
J (Former Senior Executive)	Psychology			
K (Channel Controller)	English and Classics			
L*	English			
M (Producer-Director)	Biochemistry		Biochemistry	Biochemistry
N (Senior Executive)	Physiology and Pharmacology	Science Communicatio n		
O (Editor)	No Science Degree			
P (Executive Producer)	Engineering			
Q (Executive Producer)	Politics and Philosophy			
R (Presenter)	Physics		Physics	Physics
S (Senior Executive)	Politics & Chinese			
T (Presenter)	Earth Sciences		Earth Science	Earth Science
U (Senior Executive)	Zoology			
V (Presenter)	Physics		Physics	Physics
Key: = SCIENCE = NON-SCIENCE = BORDELINE CASE	Total (excluding non-science TV interviewees): = 12 science 6 non-science 2 borderline cases 2 borderline)	Total: 1 masters in sci. com.	Total: 7 science PhD's, 1 borderline	Total: 4 post-doc and beyond (3 of which are academic presenters)

APPENDIX 4

This appendix provides further details of the quantitative analysis of the programmes analysed in chapter six.




Percentage of segments containing examples of individual coding categories over both episodes of each programme
Percentage
0
5
10
15
20
25
30
35
40
Creation Story
E Omni-C
Revealed
Immutable
Meaning
An Account
"Further Research is Required"
Technical Skill
Changeable
Ambiguous
Coding Category
Wonders of Life
Bang! Goes the Theory

APPENDIX 5

This appendix provides a generic version of my interview schedule. Each interview schedule was modified for each interview, to build on previous interviews and address specific aspects of individual interviewee's career experience. The following provides a generic account of the kinds of questions I asked in my interviews.

Interview Schedule Plan

What am I trying to find out?

How do different styles of communication/portrayals develop/come into being?

What do I need to ask?

Professional Experience

Overall professional experience: How long have you worked in Television?
What projects have you been involved in and what was roles have you had within those productions?
At what point in your career did you start making science programmes?

Specific professional experience :How long have you worked in science TV?
What and how many docs/programmes have you made? Who for/commissioned by whom?

Depending on who is being asked: Thinking about your current role or the role you have worked in for the longest, can you describe your role as executive producer, series producer, producer, director, commissioning editor, editor, researcher, cinematographer, presenters – *whether scientists themselves or not (e.g. Brian Cox)?*

Input: How much input do you have into the appearance of the final cut of the television programme?
If lots, how much? If not much, why not?
What else influences the development of a programme?

Originality/Similarity

In general, how original are you or the teams you have worked in trying to be when making science documentaries?

How much and what prior professional experience is brought into the making of science documentaries?

If you have made other kinds of documentaries, how similar is making science documentaries to other documentaries? What is unique about making science documentaries compared to other types of documentaries? How different is it?

(Drawing on Bouse) – Do you or have you made wildlife/natural history programming? *(especially when talking to BBC people*) – e.g. the BBC is world renowned for its natural history programming – do you draw on that tradition when making science programmes with a focus on other sciences and not wildlife or natural history?

Do you think there are differences in the style of a natural history programme and a science programme, or are they fairly similar?

Do you think there should be more similarities or more differences between science documentaries and natural history documentaries?

Should science documentaries look like other forms of documentary e.g. reflexive, expository?

Pressure/Tensions

What are the pressure felt when trying to communicate science?

Is there a tension between the documentary makers art and scientific knowledge/practise/endeavour?

During the creative process do you feel there a is a conflict between the imperatives to educate and to entertain?

If so which imperative tends to win out?

How influential is the channel the programme is commissioned for on the final shape of the programme?

What about professional pressure to produce programmes that are well received by fellow documentary makers?

How much consideration is given to audience reception/ratings when making science programmes?

Production Process and the Art of Documentary

What is role of post-production/CGI/continuity editing techniques – how important are these phases in producing the finished programmes?

Do you think they should be more/less important?

What is trying to be achieved with the use of CGI/what does it add to the programmes?

What is trying to be achieved with continuity editing (if it is used)/what does it add to the programmes?

How important are the other artistic elements of the documentary; framing of shots, soundtrack and its interplay with visuals?

What do these add to the programmes/do they detract from elements of the programmes?

Styles

E.g. could be more relevant for commissioning editor/someone with oversight of a broad range of science programmes –

There appear to be a broad range of different types of portrayals of science in non-fiction television e.g. a 'blue chip' programme like Wonders of Life compared to a more current affairs style format of Bang! Goes the Theory or something like Dara O'Briain's Science Club which has elements of a chat-show format

Do you recognise these as different styles?

From your perspective, how much conscious effort is made to make a science programme in a particular style? – Do programmes organically develop or is there a clear idea from the outset of what style is trying to be achieved?

What do you think is the intention of these different styles?

if you are a head of channel or commissioning editor: what is your aim in having this broad range of styles on your network?