Heroes in science: Inspiration, influence and engagement

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Declaration

I certify that this thesis does not incorporate without acknowledgement any material previously submitted for a degree or diploma at any university and to the best of my knowledge and belief does not contain any material previously published or written by another person, except where due reference is made in the text. The empirical work described within was not carried out with any other person but is my own original work.

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Abstract

Studies in many countries have examined the importance of role models, mentors and graduate supervisors in science, and some have explored the short-term impacts of science role modelling programs on young people’s engagement with science careers. Yet despite the prevalence of programs to identify, celebrate and utilize ‘science heroes’, there is a lack of systematic or significant research into the phenomenon of popular science heroes and their careers, or indeed their capabilities in science communication and engagement. Furthermore, the cultural drivers for effective communication in science are not well described; whilst numerous studies have suggested the presence of various behavioural norms within scientific cultures, little consideration has been made of communication norms and their significance within the cultures of science. The problems of influence by and on science heroes, the barriers and enablers of their potential impact and their potentially significant role within science cultures therefore form the basis for this dissertation.

The thesis takes a broad view of science heroes as communicators of influence, exploring the life histories of a subset of those nominated as science heroes to identify influences on their career pathways and life-long engagement with science, their experiences of success and of communication and the significant issues, ideas and outcomes that arise from those experiences. In-depth interviews were conducted with 100 individuals in Australia, the United Kingdom and North America, including 7 for the purposes of communication context. The questions asked about many aspects of participant life experiences, including early interests and pathways in science, key motivators and influencers including ‘inspirational others’, experiences of communicating with others in a professional context, including interactions with peers, public audiences and the media, and individual communication attitudes and approaches.

Based on analysis of this data, the thesis identifies the communication characteristics and attributes of science heroes and explores the communication practices that contribute to their relative success. Evidence is presented for the
power of narrative communication techniques and the use of heroic archetypes in projecting stories of success. Evidence is also presented for the presence of powerful norms and counter-norms in science communication.

The study builds on and contributes to work exploring the nature of influence in science career pathways, providing insight into the influences of contemporary science heroes and significant factors affecting science engagement and achievement. Additionally, the thesis extends the concept of normative practices and processes within science, making a case to include communication norms and counter-norms in the understanding of contemporary science.
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Chapter 1: Introduction

1.1 Overview

This study is about the role and value of science heroes in people’s lives, both in terms of informing perceptions and representations of science within society today, and in informing and inspiring successful careers in science (and related fields).

Within the study, science is broadly defined to encompass both STEM - the ‘traditional’ sciences and related fields such as technology and computing, engineering and mathematics - and science communication. This breadth is both useful and necessary when considering how diverse the interpretations of science have become in a globalised world; indeed as the historian Steven Shapin reveals in *Science and the Modern World*, society no longer insists on massive differences between science and technology, or between the role of scientists and engineers (Shapin, 2007). Today, research is often cross-disciplinary and a career in science or technology means following not one single pathway, but many. Scientists carry out research activities and lead or contribute to innovation, and as many studies have shown they also participate in complex communications about their work and its meaning.

Within the study, science heroes are also broadly defined. Hero is a subjective term for those who, in the opinions of others, are persons of distinguished performance or courage, or those who are invested with heroic qualities (n.a. 2014b, Macquarie) as well as those who exhibit heroic behaviour and are regarded as model or ideal (n.a. 2014c, Dictionary.com). Many diverse science heroes were suggested for inclusion in this study, by people expressing a personal opinion in a wide variety of forums and loci including in the academic and grey literature, the public domain, online in discussion forums and on websites dedicated to the topic, and in personal discussions and interviews with the author. These nominations will be discussed in more detail within the Methodology section but
for now, suffice to say that those appearing in these pages represent just a fraction of those science heroes, living among us in the early part of the 21st Century, who were worthy of inclusion.

1.2 Background to the study

The story behind this research begins over a decade ago, when England’s then Department for Education and Employment (DfEE) pronounced the need for a ‘year of science’, in a long tradition of government-sponsored ‘Years of…’ (Paine, 2016). Officially launched in September 2001, Science Year became a major campaign to promote science to young people, developed in response to long-held concerns within government about looming skills shortages in science and technology and based on evidence of a declining interest in science studies amongst young people (NESTA, 2000). It also responded to criticisms of the deficit model of science communication, conceptualised following the Royal Society’s influential Bodmer report of 1985. Exhorted to communicate much more actively about their research (Bodmer, 1985), scientists’ communication efforts were subsequently put under the microscope and their numerous failings well documented by the turn of the century (Miller, 2001).

The Science Year campaign was one of many ways in which UK institutions sought to respond to these challenges. With a focus on delivering innovative new programs, it aimed to increase young people’s engagement in science by celebrating national achievements and creating positive experiences in science and technology both in and outside schools (DfEE, 2000). To achieve its aims, the campaign targeted two key audiences: children aged under 16 and the adults known to support their educational decisions and outcomes - namely teachers and parents. The programmed activities were to include live science shows and performances, national science experiments and kits, public lectures and touring exhibitions, interactive education resources and many other initiatives designed to increase science learning, engagement and participation. All were to be supported by strengthened networks and an extensive online and media promotions strategy.
As a signature initiative of government and with considerable supporting resources from the private and public sectors, funding flowed for Science Year. In an ambitious, time-constrained delivery environment I was engaged as a program manager, working as part of a small team to bring both funded and internally managed projects to fruition. Considered ground-breaking for its time (NESTA, 2006), our programs were intended to raise the attractiveness of science as a future possible career path, primarily through stimulating the imaginations of young people and teachers (ASE, 2001). One approach we would use to achieve this goal was the active recruitment of notable individuals to appear in the campaign as heroes, champions and role models for science and innovation. Within the campaign team we believed that by selectively profiling ‘inspirational others’, we might highlight the potential rewards of science and technology careers, break down negative perceptions of scientific expertise, and foster positive perceptions of science learning.

Consequently, many scientists, innovators and celebrities across the UK were asked to contribute to Science Year. Letter-writing and lobbying secured their participation in diverse activities, including the construction of the world’s biggest DNA model (Jones, 2003) and a national speaker’s program targeted at teenagers. Research organisations were encouraged to release their most inspiring and charismatic scientists to visit schools and give presentations about their work, to assist with local Science Year events and activities and to support after-hours science clubs springing up in their local areas. The DfEE also announced new funding for a national outreach program into schools, known as the Science and Engineering Ambassadors Scheme (SEAS). Destined to become a model for science outreach in many countries, the program sought to place young scientists directly into schools where they could act as inspirational and motivational role models for students and help to build the science knowledge and teaching confidence of teachers (DfEE, 2002).

In the planning for such programs, our focus was on preferentially recruiting charismatic individuals who could actively inspire and engage teenagers and
school-aged children with science. As the Director of Science Year, Nigel Paine, later recalled:

Our key aim was to engage and enthral young people, and role models played a large, but not exclusive, role in meeting that aim. We wanted to pay tribute to the great engineers and scientists by inviting them to lecture to groups of young people and share their insights, but we wanted to turn some young scientists and engineers into relevant role models so that young people could look at them and learn about their career and feel strongly that “I could do that” (Paine, 2016).

Members of the campaign team had a range of perspectives on the qualities that an individual would need to possess in order to build relationships with their audiences. These views were derived from the diverse professional and personal experiences of the team members, and firmly rooted in philosophies of education, public relations, behavioural psychology and communication theory. Subsequently the Science Year team was able to identify a number of selection criteria for those individuals who would be charged with inspiring the Science Year audience, and in particular for those ‘key attractors’ who would appear as keynote speakers and featured participants in the most high profile public programs. The group agreed that the most successful participants could not only credibly and effectively represent STEM but would also appear contemporary, dynamic, enthusiastic, successful and involved in work of particular significance and relevance to young people (French, Duncan, McNaught, & Paine, 2008). This thinking reflected the social constructivist theories of science learning of the time, which according to later accounts were also percolating throughout the informal science learning sector (Perera & Stocklmayer, 2013).

Yet the participation of such carefully selected spokespeople for science was met with mixed success. Some, like physician and broadcaster Robert Winston, attracted sell-out crowds, whilst others barely filled the front rows. Some had attentive audiences that seemed to hang on every word and mobbed the speakers afterwards, whilst others appeared to struggle to keep the interest of the crowd.
Here then were two interesting problems: of these individuals, some were clearly more effective as communicators than others. But the precise qualities and attributes that contributed to their relative success remained unknown. Similarly, whilst we had envisaged – and consequently marketed – them all as ‘science heroes’, some clearly had a better ability to summon and excite a crowd than others. In short, these science heroes had varied public appeal; the ‘key attractors’ were not all equally attractive. But why? Each was materially successful in their field, had made public appearances before and enjoyed some degree of public profile amongst the target audiences. All events were supported by a dedicated program officer who ensured that each speaker was actively marketed to their target audience, in a similar style and tone, with an approximately equivalent amount of investment in resources. Evidently there were many variables at work but it was impossible to know which might be important.

Later unpublished evaluations of Science Year suggested that, of the many hundreds of different Science Year initiatives, those programs utilizing scientists and celebrities to engage public audiences rated well on measures such as how many attended, the quantity and tone of media coverage, and positive perceptions by local organisers. However, nothing was known about the relationships that might pre-exist or have been formed between the science heroes and their audiences, or the skills and techniques they might have used to excite and engage. These gaps in knowledge helped to create my enduring interest in the mechanisms of communication and the processes by which different individuals engage their audiences with science. Importantly, in wondering why and how the ‘right’ individuals might make an impact on others, questions relating to how personal pathways into STEM are forged and the role that communication plays in achieving relative success also began to emerge.

It seemed apparent that the answers to questions of why any individual pursues a pathway into science surely lie somewhere within that person, the lead character in their own personal narratives of a congruent and effective self-identity in science. And the answers to questions of how individuals pursue these pathways surely lie somewhere within the unique combination of personal experiences
they have had, decision-points they have reached and actions that they have undertaken. The interactions between all of these variables must necessarily be many and complex, differentially informing and shaping individual experiences of identity, the interpretation of events and the courses of action that appear to be available. Overall, one might conclude that each individual’s pathway into science forms over time, moment by moment, progressively at the individual's own hand and, if science heroes have any utility, also at the hands of others.

It is this centrality of the individual - their decisions, experiences, talents and capabilities, their constructions of reality and their empowerment as the chief actor in their own relationship with science - that ultimately forms the basis of this thesis. This investigation focuses on the experiences reported by science heroes as being important in the creation their own pathways into science and, through their proximity and availability (whether real or imagined) in contributing to the pathways of others. The research questions are informed by learning theories of social constructivism, behavioural theories of motivation, modelling and success and by communication theories including reception, persuasion and influence.

1.3 Science heroes in contemporary science communication

It is clear from the Science Year experience that science heroes, role models and spokespeople play an important role in cultural life, at least insofar as individuals from STEM-related fields may be recruited by organisations to the cause of promoting or furthering public engagement with science. Yet their purposes do not stop there; as this study shows science heroes play an important role in scientific cultures and contribute to many aspects of how contemporary science is received and interpreted, and it is to these matters that the discussion now turns.

Since 2001, programs with a focus on inspiring a new generation of scientists and scientifically literate citizens have flourished around the world. Inspiration-focused programs such as SEAS now have many variants worldwide, and
continue to attract high rates of participation by scientists and schools. Comprehensive evaluation of such programs is rare and in many cases the data remains unpublished. However according to testimonials such as those presented on the SEAS website, many participating scientists are motivated by a genuine desire to help inspire the next generation or to alter young people’s attitudes towards science and technology careers (STEMNET, n.d.). Similarly, a recent evaluation of the Australian Scientists Into Schools (SIS) program found that the majority of scientists participating wanted to improve science education and encourage students into science, with almost one quarter having a specific interest in alerting young people to science careers (Rennie & Howitt, 2009). Such attitudes may respond to calls for a higher proportion of scientists to get involved with public engagement, such as those made by The Royal Society n.a. (2006).

It is clear that science ‘heroes’ are widely used to attract and engage the attention of public audiences and to raise the profile of the sciences and related fields such as innovation and enterprise. In annual prizes, awards ceremonies and publications worldwide, science heroes are routinely identified and fêted by governments, science agencies, research organizations and popular media outlets. Perhaps this is most visible in the case of the Nobel laureates, who on receipt of a Nobel Prize are inevitably drawn into promotional campaigns that position them in front of school and university students and public audiences, where their inspirational achievements can be discussed, unpacked and ideally also transferred (Heikensten, 2015). Similarly many nations award lucrative prizes to top scientists and communicators, and then engage them in speaking tours and promotional campaigns; examples of such awards include Australia’s annual Prime Minister’s Prizes for Science, and Eureka awards, but different iterations of such national awards are apparent in most developed nations.

One might surmise from this that there is a proliferation of programs aimed at identifying potential or actual heroes of science and then using them to promote various causes, such as a greater uptake of careers in science or improved scientific literacy and citizenship. Many initiatives seek to demystify and increase
the appeal of science careers, by asking scientists to describe their work in lively, accessible ways; current examples include online campaigns such the World Wide Day In Science, which originated at the University of New South Wales in Australia, and I’m A Scientist, Get Me Out Of Here which was created by the Wellcome Trust in Britain.

In some cases ‘inspirational scientist’ programs appear to be developed primarily as a form of public entertainment, such as Channel 4’s FameLab, which places young scientists in a televised competition to communicate their research in the liveliest way possible and the Rough Science series that featured on British television screens in the early 2000s. Science festivals and museums also regularly recruit well-known science experts and celebrities to their programs as a means of attracting public audiences to their venues, together with the media on whom they rely to generate publicity (many recent examples are provided in the annual speaker programs offered by the Cheltenham Science Festival, Edinburgh International Science Festival and Australia’s National Science Week program). Elsewhere, in the media, magazines such as TIME and New Scientist also produce annual ‘heroes of...’ stories in science and related fields, including technology and the environment.

Such a proliferation of effort focused on bringing individuals to the fore as heroes for science suggests that they are effective, at least on the level of being attractive to audiences; after all, it seems improbable that commercial enterprises such as television networks, festivals, popular magazines and venues such as science museums would continue to support such programs year in and year out, were this not the case. Certainly the fascination of public audiences for individual scientists is scarcely a new phenomenon. Scientists have been drawing crowds since at least the time of the European Enlightenment in the 18th and 19th centuries, when the “public presentation” of science became a collective project and public discourses and demonstrations of scientific methods and discoveries gained great popularity (Schiele, 2005). Modern scholars have noted that learned individuals became popular ‘heroes of science’ at this time, gaining public
recognition and critical acclaim by virtue of their roles as scientific spokespeople (Hankins, 1985).

Despite this long history, popular science heroes remain relatively unstudied as a group; while biographers have documented the unique lives of many noteworthy individuals, and sociologists have studied the communities and practices of science, the personal relationships between scientists and their audiences remains something of a mystery. That they do interact is clear, as shown by one recent study documenting the social significance of celebritising scientists (Fahy, 2010). However, how they interact and the effects of this interaction at either individual or societal level remain elusive.

This relative lack of knowledge is perhaps surprising in light of the communication culture that pervades modern science; indeed Merton (1973) described science as an inherently communicative culture, and, if anything, this aspect of science has been greatly enhanced over the intervening years. Today’s scientists are in many cases both encouraged and trained to possess the skills required to communicate with public audiences, an idea that has regained momentum since the 1980s, following widespread attempts to mobilize support for science in the wake of the Bodmer Report. Commissioned at a time when funding for science appeared to have stagnated in the UK, Bodmer (1985) built a strong case for increasing the flow of information from scientists to the public. It should be noted that the one-way (deficit model) mechanisms his report favoured have since been supplemented with more complex communication models of dialogue and mutually respectful participation, part of what historians such as Bernard Schiele regard as a revival in the science “publicization project” (Schiele, 2005).

Whatever their preferred communication models, many governments, learned bodies and funding agencies now allocate resources specifically to support science communication activity; the Australian Research Council (ARC) is a case in point, allowing up to 2% of research project funds to be allocated towards dissemination activities annually (ARC, 2011). Similarly, in its May 2014 federal
budget the Australian Government allocated $28 million over the forward estimates to national science communication and promotion initiatives, whilst simultaneously cutting hundreds of millions from science research itself. When this funding was restored in 2015, the funds allocated to communication and promotion also increased ("National Innovation & Science Agenda Factsheet 18 - Inspiring a nation of scientists," 2015).

Whilst the list of specific funding initiatives is immeasurably longer than can be detailed here, organisations with significant resources expressly dedicated to scientists’ communication activities include the UK’s Royal Society, Royal Institution and British Association for the Advancement of Science; the American Academy for the Advancement of Science; Australia’s CSIRO, the Royal Institution in Australia (RiAus), the Australian Academy of Science and Science & Technology Australia.

A drive to promote and encourage communication by scientists is also clearly visible at many other levels of society. Governments annually allocate substantial funding to science communication strategies and programs, including (but far from limited to) national Years and/or Weeks of Science campaigns. In Australia alone, two recent reviews of science communication activity have found that Federal Government departments and agencies collectively resource dozens of separate initiatives each year (Questacon, 2005); indeed this disparity gave rise to the ‘Inspiring Australia’ agenda, which sought to increase cooperation between agencies and maximize the impact of science communication initiatives. Universities, too, are actively engaged in building and promoting science communication skills; at the Australian National University, for example, researchers undergo media and communications training to prepare them for public engagement activities, while databases are kept of scientists who are skilled at speaking through the media to public audiences.

This wide range of support for science communication activity seems motivated by a powerful, underlying narrative: that inspirational scientists have an important or even critical role to play in engaging public interest and attracting
the next generation of scientists. Indeed, the call for more such individuals to appear is a not-infrequent refrain; take for example a relatively recent “call to action” made by the founder of the USA Science and Engineering Festival:

Where are the heroes and role models in science and engineering? In our celebrity-driven society...the work and achievements of scientists and engineers often go unnoticed by kids...as a society we don't provide students with adequate interaction with role models in such professions, and we fail to demonstrate to kids how important science and engineering are – namely their roles in saving lives, curing disease, keeping us safe and making our lives richer every day (Bock, 2010).

Such calls are underpinned by assumptions regarding the impact that science heroes may have, with a sense that these impacts are both transformative and intergenerational. Such sentiments are apparent in many accounts, including one written by Australia’s former Finance Minister, Lindsay Tanner, referring to the television program Why Is It So? featuring the iconic physics professor, Julius Sumner Miller:

One of the first [television] programs I was entranced by was called Why is it so? It was designed to stimulate an interest in science among young viewers... I was already a humanities type, deeply fascinated by history, so the show didn't inspire me to devote my life to science. But the mere fact I was so captivated by it and can remember it vividly more than 40 years later says something about its power. There must be many Australians who were first inspired to pursue a commitment to science by the flamboyant professor (Tanner, 2010).

Equivalents to the ‘flamboyant professor’ can be found in many places, from radio and television shows to newspaper columns, the blogosphere, science festivals and outreach programs. Everywhere we look we may find singular individuals whose skills, talents, personalities and life experiences are employed in the spruiking, promotion and critiquing of science. In showbiz terms, they are known
as ‘talent’; people who are a source of entertainment and information, able to provide diversion or to deliver a message with charisma and conviction.

Complex public debates (such as those around climate change, genetically modified crops or coal seam gas extraction, for example) also call for spokespeople who can help audiences to make sense of the technical factors involved. Celebrity scientists are employed by government agencies to sell policy to the public, as in the recent, controversial case of Dr Karl Kruszelnicki, who was engaged to promote an Australian government-commissioned report into intergenerational issues (Mannheim, 2015). Media demand for science experts is such that organisations now exist for directly connecting scientists and the media; a single call to the Science Media Centre in Australia or England, for example, will almost instantly connect journalists with scientific spokespeople willing to be interviewed, and vice versa. Meanwhile, the development of on-screen scientific characters in Hollywood blockbusters and television shows are informed by the Science and Entertainment Exchange, a purpose-built network connecting scientists with writers, directors and actors.

Actors aside, what is it that makes some individuals better science talent than others? Besides filling airtime, what impact do such individuals have as a result of their communication? Importantly, very few of the programs that seek to promote scientists as ‘talent’, profile them as role models, or position them as science ‘heroes’, have been accompanied by any significant research. This study seeks to address this lack of knowledge in a number of ways.

1.4 Overview of the research objectives and thesis synopsis

This thesis defines the purpose and function of science heroes and examines how and why some individuals have become more clearly associated with science in the public domain than others. To achieve this it reviews a wide range of source information about the nature, importance and function of science heroes.
The thesis also endeavours to answer a number of key research questions that emerge from the literature, specifically:

1: What experiences characterise the science pathways of science heroes?

2: What are the communication characteristics of science heroes, and what can these characteristics tell us about the archetypes of science?

3: How do the norms of science intersect with heroic storytelling about science, and what consequences do these have for those individuals singled out as science heroes?

The results of the literature review and a discussion of the research questions arising from it are presented in detail within Chapter 2: Literature review.

This study identifies and uses as the subject of its research a cohort of individuals who have been actively marketed and/or regarded as science heroes in recent times. The study methodology is described in more detail within Chapter 3: Methods, which summarises the desktop and interview research techniques used to identify individuals for inclusion in the study and the qualitative research techniques used to document, explore and analyse their unique pathways into science, the characteristics of their communication with others, the impacts of that communication, and the key sources of inspiration informing the science heroes’ journeys towards inspiring others.

The study presents the findings and discusses their relevance to current science cultural and communication practices. The results are presented in Chapters 4-6, which address: The key influencers of science heroes; Concepts of success and celebrity in science; and science communication strategies and norms.

The study concludes by drawing inferences from the findings, making recommendations in terms of individual and organisational science communication capabilities and outlining potentially fruitful directions for future research.
It is hoped that these findings will have relevance to those seeking to encourage and engage in public engagement with science through the use of personal science heroes and role models. Those to whom the research may be particularly important include individual scientists involved in presenting science to the public and whose intention is to inspire a new generation; organisations and agencies investing in science communication programs and strategies that require the involvement of inspirational individuals to succeed; media agencies who rely on ‘talent’ associated with the world of scientific research; and researchers in the field of science and technology communication for whom this work may represent a small step forward.

1.5 Scope and limitations of the study

The study endeavoured to address the research questions while working within key limitations typical of all research, such as completion within a reasonable timeframe and working within the limited budget and research resources available. These factors necessarily restricted what could be achieved, including the amount of data that could be collected, the locations from which data could be obtained and the degree of data analysis undertaken. These limitations have informed the design of the research, which is described and discussed in detail within the Methods chapter. A number of other key limitations should also be noted at the outset, to help put the research into perspective and guide the reader in interpretation of the results.

This study of science heroes is not a whole-world study, but is limited to individuals living in Australia, the United Kingdom and North America in the present day. Its subjects are all English-speakers, primarily situated within the social cultures and sub-cultures of Western science rather than in other forms of knowledge generation, such as indigenous ways of knowing or religious belief systems. The decision to exclude individuals who did not clearly meet these criteria was aimed at improving the ease of data collection and increasing the likelihood of similar social and cultural frames of reference in regards to STEM. However, there remains a potentially infinite number of variables that can
influence an individual’s pathway into and experiences of STEM, their communication characteristics and personal qualities, and all of these can be expected to vary from person to person and culture to culture. Therefore the application of these restrictions does not create a homogeneous dataset from which population-level generalisations can be made. Nevertheless, it does enable some useful findings to be made in relation to science heroes who share the traditions and norms of contemporary Western science.

Limitations to the study also come from being a single researcher, with sole responsibility for gathering, processing, analysing and reporting on data. To help ensure the data collected was relatively robust, some was excluded from the scope, including data obtained from unverifiable sources or derived solely from my own personal experience. Being myself a product of a STEM education in the Western scientific tradition, my own heroes could be validly nominated to the study; however to reduce the risk of confirmation bias, I developed a protocol to require further evidence of their heroic status from independent sources before including my own heroes in the data set.

In reporting the results of this study and developing this thesis, I have relied on the evidence presented by the primary data, which are first-person accounts obtained from known STEM heroes. Nevertheless, from time to time my personal reflections and experiences in the course of collecting the data have provided important insights into the phenomena under investigation, including the impacts of meeting one’s heroes, interaction effects between interviewer and interviewee, and the impacts of celebrity on individuals as they interact with fans, fellow scientists, the media and the wider community. Where personal reflections and stories from the research process are included in this thesis, they are clearly marked as such within the text.

In the following chapter I will review the literature that has informed this study, and which provides the context for the research methodology that follows.
Chapter 2: Literature review

2.1 Chapter overview

This literature review seeks to define the origins, importance and function of science heroes, their pathways to success and the role they play in inspiring others’ pathways into science through their communication efforts. Several key research questions emerge from this review, as summarized at the end of the chapter.

2.2 Science and the universal hero

Throughout time, heroes have played an important role in storytelling and human culture. Both mythology and social systems for distinguishing individual status are amongst a limited number of traits that anthropologists find occurring in all human cultures (Fox, 2005). Analysing centuries of human mythology in his seminal work, The Hero with a Thousand Faces, historian Joseph Campbell elucidated the importance of hero figures. In highlighting the recurring hero motif of myths throughout time, he identified the ‘monomyth’ of the hero’s journey, a universal story of adventure and transformation that runs through all of humanity's mythic traditions (J. Campbell, 1949).

Popularised for use by the creative industries in the 1980s, Campbell’s work ran parallel to Carl Jung’s theories of the collective unconscious and its archetypes; those recurring, primordial and universal images and motifs from which humans derive shared meanings and understandings (Piepmeyer, 2007). Subsequently many late-20th century writers have applied the key elements of Campbell’s work to different genres of storytelling, including film, television and literature; a practice effectively validating the assertion that all stories can be understood in terms of the monomyth (Vogler, n.d.).

Within popular culture, stories about scientists and the nature of science also persist over time. Scholars such as Haynes (2003) have identified a limited
number of stereotypes within stories about Western science since the 17th century, which include positive depictions of the ‘hero scientist’ or the ‘scientist as explorer’ and negative incarnations of the evil, mad or uncaring scientist (Haynes, 2003). These depictions can also be understood in light of Campbell’s monomyth, when key stages of the hero’s journey are mapped against ideas central to the practice of modern science; these include the experience of finding scientific inspiration (Campbell’s ‘call to adventure’), the challenge of facing difficult tasks, obstacles or opposition (a ‘road of trials’), the discovery of important scientific knowledge (‘the boon’) and the effort of bringing this knowledge to the world (‘application of the boon’).

While some researchers have found that negative stereotypes of scientists are common in film and literature (Tudor, 1989), others have found the opposite (Meredith, 2010); certainly within broader popular culture stories of scientists as heroes abound, as exemplified through discussion forums and websites dedicated to sharing positive stories, such as those found at www.myhero.com and www.scienceheroes.com. One example, a case study of Sir Howard Florey drawn from a website for school students, in some ways neatly encapsulates the monomyth; the key aspects of the narrative that appear to trace the hero’s journey, from the call to adventure to application of the boon, are italicised here for emphasis:

Florey headed a team of British scientists that were on a journey to find a substance that could destroy bacteria...Florey created and led the team that discovered penicillin...The team worked...overcoming numerous excruciating scientific difficulties, all while...a German invasion during World War II threatened to stop their research. Later, this monumental achievement was honoured when Howard Florey, Ernst Chain, and Alexander Fleming received the Nobel Prize...for their contributions in bringing penicillin to the world. (Allie, n.d.)

Such entries are typical of websites dedicated to celebrating the achievements and contributions of individual heroes, scientific or otherwise. The references to
leadership, to assistance, to journey, to risk, to difficulty, to finding new knowledge and bringing it to the world for the good of humanity, all echo the key stages of the hero’s journey. Florey and his colleagues represent what Campbell called ‘universal heroes’: those who bring a message for the entire world. But there are also local heroes in Campbell’s typology: those who bring their knowledge to their own small group of kith or kin (J. Campbell, 1949). Science heroes, then, may be widely known and acknowledged (as is the case with the Nobel Laureates) or only locally known (as is the case of those whose achievements have had an impact on smaller communities of family, students, colleagues and acquaintances). Thus whilst Einstein may be a household name, with Tourette, Feynman and Curie close behind, few outside their fields will have heard of local science heroes such as Hitchings and Elion, Kountz or Bohlin. These individuals are all scientists featured on the scienceheroes.com website; Hitchings and Elion were biochemists, who developed rational drug design and systematically discovered many lifesaving drugs; Kountz was an African-American medical scientist who developed crucial techniques for kidney transplants; Bohlin was an engineer, employed by Volvo, who developed modern seat belts.

Some scholars have suggested that heroic stereotypes have an important role to play in the cultures of science, which are both social and competitive. As British sociologist of science, Trevor Pinch, said:

Scientists, in my experience, are some of the friendliest, most hospitable, charming, interesting people you would ever want to meet, but they need their heroes and their villains (Pinch, 1992).

In science it is common to be neither hero nor villain, but also quite possible to be both: in order to succeed, scientists must master the normative practices of science, such as those proposed by Merton (1942, 1973), Kuhn (1962) and Bourdieu (2004). As Merton remarked:
...the institution of science, like other institutions, incorporates potentially incompatible values: among them, the value of originality, which leads scientists to want their priority to be recognized, and the value of humility, which leads them to insist on how little they have been able to accomplish. These values are not real contradictories...but they do call for opposed kinds of behavior. To blend these potential incompatibles into a single orientation, to reconcile them is no easy matter. Rather the tension between these kindred values - kindred as Cain and Abel were kin - creates an inner conflict among men of science who have internalised both of them... (Merton, 1957)

Navigating this inner conflict successfully may prove difficult for some, potentially causing individuals to contradict or overstep the behavioural norms of science. These norms have deep historical roots, which stretch back to at least the time of Sir Francis Bacon. In his 1621 utopian work of fiction, *New Atlantis*, Bacon described an ideal, altruistic college of the scientific elite dedicated to serving the common good. By 1660 these ideas had reportedly inspired the formation of the Royal Society of London, which adopted Bacon’s code of rigorous experimentalism, open communication of research, and usefulness (Haynes, 2003). These founding principles can be seen reflected in the behavioural norms of science today, which favour rigour, communication and usefulness alongside other values.

In his seminal work on the sociology of science, Merton (1942) identified four key behavioural norms and opposing counter norms in science, whilst a further two pairs were later identified by other scholars. These norms, paraphrased from Anderson, Ronning, DeVries & Martinson (2010) can be summarised as follows:

- **Communality**, where scientists openly share new findings with colleagues, and **secrecy**, where scientists protect their newest findings to ensure priority in publishing, patenting, or applications.
• **Universalism**, where scientists evaluate research only on its merit, and **particularism**, where scientists’ assessment is based on the reputation and past productivity of the individual or research group.

• **Disinterestedness**, where scientists are motivated not by the possibility of personal gain but by the desire for knowledge and discovery, and **self-interestedness**, where scientists compete with others in the same field for funding and recognition of their achievements.

• **Organized skepticism**, where scientists consider all new evidence, hypotheses, theories, and innovations, even those that challenge or contradict their own work, and **organized dogmatism**, where scientists invest their careers in promoting their own most important findings, theories, or innovations.

• **Governance**, where scientists are responsible for the direction and control of science through governance, self-regulation and peer review, and **administration**, where scientists rely on administrators to direct the scientific enterprise through management decisions.

• **Quality**, where scientists judge each others’ contributions to science primarily on the basis of research quality, and **quantity**, where scientists assess each others’ work primarily on the basis of numbers of publications and grants (Anderson et al., 2010).

Researchers have suggested that while such behavioural statements will never fully describe the complex normative system of science, they can contribute to analyses and discussions about scientific work (Anderson et al, 2010). Of particular interest to this study of science heroes are the norms that relate to individual success and communication behaviours.


2.3 Heroes and the communication cultures of science

We cannot look, however imperfectly, upon a great man, without gaining something by him. He is the living light-fountain, which it is good and pleasant to be near. The light which enlightens, which has enlightened the darkness of the world... (Carlyle, 1840)

The nineteenth century Scottish philosopher Thomas Carlyle, in his renowned speeches on heroes and hero worship, identified six social categories of heroes including kings, poets and men of letters. Scientists are omitted from this list per se, but mentioned throughout his speeches; he was writing at a time when Enlightenment values of rational thinking and scientific progress had been supplanted by Romanticism’s ideals of “the individual, the subjective, the irrational, the imaginative, the personal, the spontaneous, the emotional, the visionary, and the transcendental” (Encyclopedia Brittanica, 2014).

It could be argued that such idealism enabled scientific heroes – and villains – to prosper in post-Enlightenment Western societies. Against a backdrop of industrial revolution and accelerating technological development, the value of science in the 18th and 19th centuries was bolstered by widespread communication about new scientific and technical discoveries, which were exhibited on both a grand scale, as in the case of the Great Exhibition of 1851, and on a smaller and more personal scale, at public lectures and demonstrations that collectively enthralled their audiences. As historian Terrell (1998) observes:

Narratives of discovery, and in particular heroic discovery, promoted the value of science...they elevated the heroes of science above the rest of humanity (Terrell, 1998).

Scholars have argued that such narrative communication was necessary as a result of the changing nature of science in Victorian times, characterised by the increasing technical specialisation of scientists (Lightman, 2007) and the pervasive role of science in contemporary culture, which served as a source of empowerment, entertainment and self-education at all levels of society
(McLaughlin-Jenkins, 2003). Those who undertook to communicate science had varying social, political and ideological motivations for their activities, from the professional scientists seeking to secularise science and shore up their own authority to the ‘popularisers’ who sought to build a sense of awe and wonderment around the natural world for religious, moral or commercial purposes (Lightman, 2000). Presenters and popularisers of science appear to have been as much part of mainstream science as of public discourse. Despite some critics’ disdain for the “dilettante in science proud to make small talk out of Huxley’s or Tyndall’s lectures, inflated with fallacies of his or her own extraction” (Lightman, 2007), conversations and presentations about science flourished (McLaughlin-Jenkins, 2003). The narrative devices employed by popularisers included blending fact with fiction and inviting audiences to see themselves as participants in the ‘quest for knowledge’ (Lightman, 2000).

It is easy to see how stories about the activities of scientists can be relayed in the heroic tradition; indeed, history reveals that scientists are more than capable of positioning themselves thus. An example of Haynes’ ‘hero-explorer’ stereotype can be drawn from the 19th century explorer-zoologist Paul du Chaillu, whose scientific expeditions to Africa were closely followed by popular writings and dramatic exhibitions of shot and decapitated gorillas (Lightman, 2007). Attracting large audiences, du Chaillu’s public displays, lectures and books carried deliberate subtexts of epic journey, unknown dangers and heroic survival; as he wrote in the introduction to Wild Life Under the Equator, a book for children:

...I loved to roam in wild and distant countries; I loved to look upon and study the men, the beasts, the birds, the fishes, the insects and the trees. I had no-one with me, but God was kind to me, and took care of me, and he has now brought me back safely so that I might tell you all I have seen (du Chaillu, 1869).

The idea of the lone hero going in pursuit of science, confronting, learning from and then returning with vital knowledge, is a trope that persists. Indeed, it is the
heroic achievements of the individual that underpin the reward systems of modern science, which as Merton (1953) points out is dependent on identifying and acknowledging ‘firsts’: the rewards flowing mainly to those who are first to discover and publish new knowledge. Here, communication activities enable an individual to demonstrate their expertise and leave no doubt of their primacy.

In order to make the existence of scientific work known, one must first promote or popularise it, and scientists utilise a wide range of communication mechanisms to ensure this happens. Whilst some scientists express discomfort at needing to engage in self-promotion, perhaps due to the inherent conflict between science norms and counter norms such as primacy and humility (Merton, 1957), others see it as a necessary part of professional career development. Online forums such as Scientopia, where scientists share information and seek advice, reveal that individuals promote their work in a huge variety of ways including writing to members of their existing and desired networks with news of their personal achievements and potential contributions; inviting themselves to present at meetings and conferences; organising events such as workshops and symposia; working with communication officers at their institution to prepare press releases and media appearances; applying for fellowships and grant opportunities; maintaining a professional online presence including through personal websites and social media; and self-citing in publications (Scientopia, 2012).

Scholarship examining the practices, goals and representations of Western science over almost two centuries reveals that the way it is communicated both reflects and is inseparable from its politics, contexts, norms, social meanings and relative value to different groups within society (Merton, 1957). Scholars such as Topham (2009) have in fact urged us to repudiate the “artificial distinction between ‘popular science’ and ‘science proper’” (p.1), suggesting that all science knowledge can be understood as being part of a communicative process that involves appropriation, resistance and cultural contestation. Such views are reinforced by recent studies by Fahy (2010, 2012) that have explored the
phenomenon of ‘celebrity scientists’ and the contested nature of their communication activities.

Such views acknowledge science as a cultural practice with communication at its very heart. Certainly, many Australian scientists acknowledge communication as a crucial part of their activities (Searle, 2013), with one recent international review of scientists’ communication norms and practices suggesting that scientists distinguish between internal scientific and external public communication, and that large numbers of scientists have had interactions with journalists as part of their communication efforts (Peters, 2013). There is also evidence that the public sees scientists as communicators: for example, in a study investigating perceptions of scientific stereotypes amongst school children, a significant number identified communication as a key activity that scientists can carry out to ‘make a difference’ (Palmer, 1997). From limited data available on the topic, it appears that science heroes, whether universal or local, are those that make a difference. Therefore consideration of the perceptions around how they make a difference is relevant to this research.

2.4 Science heroes in popular culture

Popular culture is thought to be a major source of information about science and scientists for most people (Bowdoin Van Riper, 2003). Tropes, a derivative of archetypes, are significant or recurring themes and motifs that appear in popular culture (Oxford Dictionaries, 2004). The hero trope has many variants that appear in all forms of drama and literature, including that of the science hero, which itself has many variations; in television alone, up to fifteen different variants of the science hero trope have been identified (n.a., 2015c). Use of hero tropes is useful in narrative forms of entertainment, in helping people to form emotional assessments of characters and rapidly generate meaning from the plot, and in helping persuade audiences of particular messages. They are also useful in science communication: for example, Van Riper (2003) suggests that heroic treatments of scientists and inventors depicted in popular culture contribute to a
shared frame of reference for scientists and the public, facilitating discussions of science and its social implications.

Winston (2010) reports that an environmental saviour trope is commonly used in wildlife films to persuade audiences of environmental values; his analysis suggests that film's environmental hero trope has evolved over time since the beginning of the 20th century from that of the 'great white hunter' (not dissimilar, in fact, to the hero-explorer image perpetuated by du Chaillu) to the ideal of 'environmental saviour' which had emerged by the end of it (Winston, 2010). Some scholars have also shed light on how the characterization of some scientists as environmental saviours has evolved in response to social, economic and geopolitical forces (Brockington, 2008).

The hero-explorer trope suggests one who pursues truth and pushes towards new frontiers of knowledge on behalf of humanity. A contemporaneous variant can be readily identified in reality TV series: for example the British-made programme Rough Science, which maroons charismatic scientists in remote locations and requires them to problem-solve their way back to civilisation. In the television programme Mythbusters, the investigators use scientific methods to prove or disprove urban myths and old wives tales, often under risky and adventurous conditions - although in this case, their work is repeated and tested against experimental controls. In both cases, the individual presenter/s are central to the narrative - they are risk-taking on behalf of the viewer, simultaneously guides to and observers of the science that is unfolding, whilst also instrumental in its practice, by 'doing science'.

Researchers such as Dingwall (2006) have found that wildlife television is a significant source of public information about biological science and environmental issues and that wildlife presenters play a critical role, being at once authoritative, respected and attracting a high degree of viewer loyalty. Indeed, such presenters may become public heroes and vice versa; iconic international wildlife television presenters David Attenborough and Jane Goodall have both been recognised as environmental heroes by TIME magazine, although
the former has worked almost exclusively as a broadcaster since obtaining his science degree whilst the latter commenced television appearances as an adjunct to her scientific research career. They are both also global brands, whose presence contributes to the prestige of the ‘blue chip’ programmes they participate in (Dingwall & Aldridge, 2006); such programmes utilise a sole, authoritative voice to highlight the splendour, drama and detail of the animal kingdom (Boué, 2000).

The grand themes addressed by such wildlife programmes are powerfully emotive and can be seen as closely linked to heroic themes: they speak of life and death, the struggle for survival, difficult journeys and close relationships in the animal world (Dingwall & Aldridge, 2006). By proximity, the wildlife presenter (whether visible on-screen or not) is part of this journey; together with the film’s subjects they persist through wild and inhospitable terrain, inclement weather, deadly attacks and crises of survival. Their survival to the end of an episode could be considered part of that epic hero’s journey; having travelled into the wilds, they return safely to share their newfound knowledge with us. Despite this, the less prestigious, presenter-led wildlife programmes, with their more open forms of narrative and greater range of opportunities for viewer engagement, are thought to be more effective at conveying both the practice and outcomes of science in all its complexity (Dingwall & Aldridge 2006, p.147).

In reviewing portrayals of scientists in film, scholars have also reported that portrayals of scientists as heroes substantially outnumber those of scientists as villains (Griep, 2010). Such findings appear consistent with research suggesting that scientists maintain a particularly trusted place in society. For example, in repeated surveys of Americans conducted between 1998 and 2001, scientists were one of the top four most trusted professions (Taylor, 2001, 2002). Similarly, a 2009 survey of American adults found that scientists are perceived to contribute ‘a lot’ to society’s well being, with only members of the military and teachers thought to contribute more (n.a., 2009). According to research into trust commissioned by the Science Museum in London, the term ‘science’ tends to be associated with ‘truth’ and ‘facts’, suggesting scientists are primarily viewed by
the public as independent truth-seekers (Dillon & Hobson, 2013). This view may help explain the ease with which heroic tropes can be attached to stories of scientific achievement.

Researchers have also found that heroic science stories have utility in the classroom. (Milne, 1998) identifies them as one of four major classes of narrative in common use. Such stories may be useful in assisting students organise their knowledge into explanatory frameworks, helping them interpret and understand their experiences in science (Milne, 1998). While heroic stories may also represent science knowledge as existing independently of the discoverer, thereby contributing to prevalent myths about what science is and how it works (McComas, 1998) they may also help students to identify more closely with scientists as they reflect individuals’ struggles to obtain a higher level of understanding (Milne, 1998).

A similar effect may be at work when hero tropes are used to communicate about science in a public policy arena. One recent investigation, which explored the effects of heroic narratives on communication about climate change policy, found that heroic narrative structures can strongly influence audience support for particular points of view. The use of a hero/villain trope assisted audiences to make sense of the information and strongly influenced emotional assessments of organisational character, ultimately generating support for the arguments and assumptions embedded within the narrative (M. D. Jones, 2014).

2.5 Heroes in scientific culture

Sociologists of science such as Pinch (1992) have argued that science is both a competitive and moral activity, where there are different categories of winners and losers. Of ‘heroic scientists’ he finds there are several kinds: quiet achievers, star performers and those who ‘listen to the material’. All are characterised by achievement and ability but differentiated by their communication styles. In the case of ‘quiet achievers’, such as the experimental chemist and Nobel Laureate,
Ray Davis, it is professional resilience and a cautious approach to establishing results that wins him favour with his peers:

Ray Davis...has smiled when silly criticism has come, let it roll off his shoulders, and when serious criticism has come has gone and invented a test...the unusual caution with which Davis presents his results...doesn’t prevent the insider from feeling the excitement that lies behind his very, very quiet cautious words. But it does have the consequence that Ray Davis is not what he should be, namely a public hero in science. (Martin Schwarzschild, quoted in Pinch (1992), p. 495)

Those who do attain a high degree of public profile, such as the physicist Richard Feynman, are characterised as having confidence, showmanship and bravado; communication characteristics, Pinch finds, that are particularly visible at times of scientific controversy, when professional stakes and public interest are high:

If you study scientific controversies, you often find these types of heroes appearing on the scene...It’s a particular style they cultivate. Quick on the draw, the catchy metaphor, never getting defensive but always managing to sound as if they speak for everyone (Pinch, 1992).

Finally, there is a ‘listening to the material’ style of science hero: those, like geneticist Barbara McClintock, who do not work to impose order on nature but listen to and comprehend what nature has to say; while their ideas may initially be unfashionable, over time these heroes retain support from their scientific community and are ultimately vindicated; they survive despite the possibility of being wrong, which as Pinch reports can have terrible consequences:

Scientists who lose in...controversies are not just failed innovators, or people with vision who did things differently - they are marginalized (often losing their status and funding), regarded as paranoid, unethical, and nowadays, if they get written up in the New York Times, even treated as frauds...(Pinch, 1992)
For those at the forefronts of their scientific fields, proposing new directions and exposing new truths has rarely been easy. To reap the rewards of science, individuals must demonstrate that they are the first, by communicating what they have found. Communicating too much, too soon means that there is a greater risk of error and of ridicule; as Merton (1957) points out, humility is also an important norm in science. Yet waiting for absolute certainty may mean communicating too late, when there is a risk of being overshadowed by competitors. As scientists from Charles Darwin to Rosalind Franklin have found, the meticulous work of years can be out-paced by those with better resources, support and communication tactics.

In summary, the heroic scientist plays a simultaneously important and problematic role in science, particularly when considered in light of science’s sociological norms, which favour humility and communalism but also reward primacy and self-interest. It is evident that the narrative of the heroic scientist strongly persists within society, including within popular culture and the stories of scientific endeavour and achievement that are used both to entertain and motivate and inspire achievement in others. Clearly, science heroes serve a range of purposes, amongst which is the modelling of scientific achievement, behaviours and skills for future generations of young scientists. To explore this purpose in more depth, it is to the sociological literature that I now turn.

2.6 Role models in STEM

Defining role models

The term role model was brought into common usage by American sociologist Robert K. Merton, famous for his studies of the sociology of science and the interplay between science and its social, religious and cultural environments (Holton, 2004). The term was first applied to a 1960s study of the socialization of medical students and is now widely used to conceptualize how individuals influence the social behaviours of others.
Several definitions of the role model are available in the literature. One views the role model as a teacher, possessing skills that can be taught by demonstration and learned through observation by another person (the modeller). Another describes role modelling as an active relationship between the model and the modeller, in which factors such as perceived similarity in values, personal characteristics and lifestyle are crucial. This latter description is thought to be particularly pertinent to close personal and professional relationships, such as those between graduate students and their faculty advisors (Gilbert, Gallesich, & Evans, 1983).

People do not always require direct, personal contact with a role model in order to make a social comparison with them, and the term ‘distant role models’ may be used to describe those who are rarely encountered or who are observed indirectly through intervening media (Pace, 2008). Distant role modelling enables relative strangers, such as celebrities, public figures and those who are no longer alive, to be adopted as effective role models. In one recent American study, entertainers and sports stars were most commonly named as role models while 96% of the science role models named were deceased (MOSI, 2007).

**The purpose of role models**

Role models are thought to provide an idealized model of individual performance and behaviour to which others can compare their current and future selves. Often, individuals will select role models who seem psychologically similar to themselves, for example sharing their sex, ethnicity, age, physical proximity, lifestyles or family ties, and those who have domain or professional relevance, for example by working in the same fields of interest (Lockwood & Kunda, 1997). Individuals will also select role models that differ from themselves at times when similar role model choices are unavailable or when different role models are perceived to have a greater professional value within their field (Gilbert et al., 1983; Wohlford, Lochman, & Barry, 2004).
Research on role models dating from the 1960s has suggested that social comparison, or comparing oneself with others, is a means by which individuals can assess their own current abilities. But more recently a role for models in the creation of future selves has also been described. Role models appear able to enhance and inspire other people by illustrating how future achievements could be accomplished and making potential future selves appear more tangible (Lockwood & Kunda, 1997).

Role models, however, may be positive or negative and both can motivate individuals to achieve. A positive role model is one who highlights strategies for achieving outstanding success, and can motivate others to pursue similar excellence. A negative role model is one who has experienced some kind of failure or misfortune, and can motivate others to avoid similar outcomes (Lockwood, Jordan, & Kunda, 2002). At different times, people may respond differently to positive and negative role models.

**The impact of role models**

The ideal role model has been described as a person who is somewhat older and at a more advanced career stage than the modeller, and who has achieved what the modeller hopes for – outstanding but not impossible success at an enterprise in which in they too would like to excel (Lockwood & Kunda, 1997).

Research from the field of social psychology suggests that the impact of role models varies with their relevance to the modeller and the apparent attainability of their achievements. It is thought that the adoption of any particular person as a role model is more likely when that person is understood as a realistically multidimensional individual who has achieved substantial and meaningful success (Lockwood & Kunda, 1997). The availability of an outstanding role model from a relevant field, whose accomplishments are perceived to be attainable, is most likely to enable positive comparison (Lockwood & Kunda, 1997; Pace, 2008).
Role models have been documented as having a range of positive impacts on the modeller, including providing hope, inspiration and motivation, acting as sources of information, giving validation for personal abilities and choices, and demonstrating personal effectiveness in relevant realms. Researchers have found that, for adolescents, the presence of a role model is also associated with earning higher grades, having higher self-esteem, and having stronger ethnic identity than their peers, and also appears to be protective against risk behaviours (Yancey, Siegel, & McDaniel, 2002). Indeed, motivation and self-image are also known to be closely linked and the best role models are likely to be those that promote a positive self-image in the modeller, providing the motivation to strive for higher goals (Lockwood & Kunda, 1999). For graduate students, the presence of a role model in the form of a mentor, a more experienced individual who deliberately provides them with support and guidance, can also contribute to long term success by increasing the number of publications and conference presentations they achieve (Cronan-Hillix, Gensheimer, Cronan-Hillix, & Davidson, 1986).

**Heroes and ‘sheroes’: role models and gender**

One observation of Campbell’s ‘universal’ monomyth is that it is highly gendered; as Campbell points out:

All of the great mythologies and much of the mythic story-telling of the world are from the male point of view. When I was writing...and wanted to bring female heroes in, I had to go to the fairy tales. These were told by women to children...a different perspective. It was the men who got involved in spinning most of the great myths. The women were too busy; they had too damn much to do to sit around thinking about stories.’ (Joseph Campbell, 2004)

Researchers have found that gendered notions of achievement have profoundly influenced the underlying structures, processes and ethics of science, highlighting the need for new approaches when constructing narratives about
science and engineering (Adam, 2001). Some call for the more systematic and deliberate recognition of heroines or ‘sheroes’ in efforts to foster mentoring and role modelling in science and engineering fields, (Broome 1996, 1997). Some have found that young women’s role models in popular culture are increasingly divergent from ‘traditional’ female ideals; rather than dependent and submissive, female lives are depicted as being financially, intellectually, socially and sexually independent of male counterparts (Hopkins, 2002).

The likelihood of having a role model does not appear to vary significantly by sex (Yancey et al., 2002). Both men and women show a preference for role models of the same gender as themselves, although women are more likely to have role models of both sexes than men are. However, females and males also show differences in the social status of the role models that influence them. Males tend to rate themselves as more influenced by famous or distant role models, while females appear more influenced by personally known role models (Wohlford et al., 2004).

**Role models and recruitment into science**

Early exposure to and interaction with professional role models is thought to be critical for recruiting students and retaining their interest and participation in mathematics and science. Yet within scientific fields, individuals from under-represented groups may have difficulty in identifying role models with psychological similarities to themselves. Women and those from ethnic minorities are both under-represented in the sciences and are more likely to have role models of a respectively different sex or ethnicity to themselves. Both groups also tend to have less confidence in their scientific abilities (Gilbert et al., 1983; Trankina, 1992), and researchers have found that the major factor affecting the attitudes of black and female students toward the pursuit of science and science-related careers is their personal contact with a scientist (Hill & Pettus, 1990).

Where similar role models are available, participation and retention rates increase. For example, traditionally black teaching colleges in the United States
produce a disproportionate percentage of black scientists and engineers, a pattern which has been attributed to the greater availability of black role models at those institutions (Hill & Pettus, 1990).

In recent years, researchers have called for intervention programs that use active mentoring to challenge stereotypes in science, and directly create stronger role models by encouraging more direct interaction between scientists and students (Cleaves, 2005; Oakes, 1990). Such programs are known to be effective at changing student attitudes towards science, mathematics and technical careers, at least in the short term (Dorsen, Carlson, & Goodyear, 2006; Wilson et al., 2011). Several countries have subsequently implemented national science mentoring and role modelling programs that are aimed at increasing overall student retention rates in science and engineering, including Australia and the United Kingdom.

2.7 Success and the science hero: finding pathways into science

As observed by science communication scholar, Chris Bryant:

Humans are remarkable for their consciousness; for their ability to reason, their self-awareness, their capacity for empathy, for remembering the past, awareness of their environment and, above all, to make choices from among many possible ‘futures’ (Bryant, 2013).

Indeed, the science learning pathways of individuals appear to develop as a result of many different learning experiences, including those provided by both the formal and informal learning sectors. As the Informal Science Education Ad Hoc Committee of the Board of the National Association for Research in Science Teaching (NARST) pointed out:

Learning rarely if ever occurs and develops from a single experience. Rather, learning in general, and science learning in particular, is cumulative, emerging over time through myriad human experiences...learning is an organic, dynamic, never-ending and holistic
phenomenon of constructing personal meaning (Dierking, Falk, Rennie, Anderson, & Ellenbogen, 2003).

Supporting views come from scholars such as David Lohman, who identifies four key influencing elements in the pathways of gifted and talented students, namely experience, mentoring, motivation and volition. He writes:

> Over the long haul, affect and volition are probably as important in the development of talent as are entry level of ability and opportunities provided (Lohman, 1995).

Such views reflect the social constructivist model of science learning, which many scholars argue provides the most useful model for understanding how positive learning outcomes in science may be achieved (J. K. Gilbert, 2013). Social constructivism emphasises the wider social context in which learning takes place and highlights the influence of social interactions and media for sharing knowledge, including personal motivations, relationships with teachers and fellow students, and the presence of text, video and audio amongst other sources (Vygotsky, 1962).

Certainly, scholars have found evidence that many diverse sources do inspire, inform and encourage engagement in science. For example, in a review of the literature around Citizen Science, Pearce (2010) reports that science-related television programming can successfully increase children’s learning, enjoyment or appreciation of science and also change their attitudes towards it; the same review also found that character role models on television also influence children’s reactions to science (Pearce, 2010).

Scholars such as Stocklmayer (2013) have succinctly highlighted the myriad ways in which science engagement may take place and how multiple sites of communication bring various publics and science into close proximity, while others have proposed that many different categories of science interest, literacy and values exist (Miller, 1983; the Wellcome Trust, 2000; Ogawa, 2013).
Social constructivist views of science learning are supported by the self-reports of science heroes, including Nobel Laureates such as Albert Einstein, Marie Curie and Konrad Lorenz. Einstein was reportedly influenced by a variety of experiences that included growing up in a scientifically literate household, exposure to the ‘wonder’ of a magnetic compass at the age of four or five, enjoying stimulating talks with his uncle - an engineer - and interactions with a medical student who ate dinner regularly at the Einstein house (n.a., 1996). Similarly, accounts by Curie of her upbringing recall the importance of both formal education and family life in science and learning:

I easily learned mathematics and physics, as far as these sciences were taken in consideration in the school. I found in this ready help from my father, who loved science...Unhappily, he had no laboratory and could not perform experiments (Pasachoff, 2000).

Despite her upbringing in czarist Poland, where women’s advanced education was widely discouraged, Curie’s self-motivation to learn appears immense; she would later go on to study advanced mathematics, having previously taught science and mathematics as a governess and studied alongside a group of young scholars at the so-called Floating University:

It was one of those groups of Polish youths who believed that the hope of their country lay in a great effort to develop the intellectual and moral strength of the nation...we agreed among ourselves to give evening courses, each one teaching what he knew best (Pasachoff, 2000).

Another more detailed exemplar comes from the account of zoologist Lorenz, who in biographical notes published in 1974 documented a large array of early childhood events that he considered had been essential to his scientific and philosophical development. From childhood he recalled: conversations with his father; being given a spotted salamander and with the help of his nanny raising 12 larvae to metamorphosis; having his imagination sparked by fiction books including *Nils Holgersson*, the story of a young boy’s transformation in the company of wild geese, which made him dream of being a wild goose; and factual
texts such as Wilhelm Bölsche’s work on evolution which, containing a picture of *Archaeopteryx*, caused him to consider the evolutionary possibility of earthworms. He also raised ducks, including a one-day old duckling that he successfully imprinted, which contributed to his life-long interest in ornithology. Relationships formed in his teenage years he reports as being both important and foundational: as a schoolboy he formed a close friendship with the future zoologist Bernhard Hellmann, with whom he examined and collected pond life and engaged in concrete discoveries of evolution. Several secondary school teachers are credited with directly encouraging him, whilst at medical school the tutelage of brilliant comparative anatomist Ferdinand Hochstatter and the ideas and mentorship of Oskar Heinroth were a major - and perhaps definitive - source of inspiration (Nobelprize.org, 2013).

Such accounts are supported by recent studies such as those by L. V. Shavinina (2013) exploring the early childhood and adolescent education of innovators and Nobel laureates in science. These paint a picture of science learning on a continuum, of opportunity and engagement occurring in many different environments, strongly influenced by the presence of individuals providing guidance, advice, pressure, inspiration skills and authority. Also apparent in such accounts are personal behaviours that can be seen as closely aligned with scientific norms: curiosity, inquiry, collecting, observation and experimentation amongst them. There are also indicators that imagination and creativity have a role to play, seeming to provide the individual both with a centrality in their own journey and new ideas about possible ways of being.

In such narratives, physical experiences also appear to be motivated and magnified by a high degree of individual empowerment and autonomy; characteristics shared with what psychologists refer to as ‘mindfulness’. Indeed, mindful states have been shown to improve learning in informal environments such as museums; in a 1996 study psychologist Gianna Moscardo found that mindfulness enables “not a single optimal perspective, but many possible perspectives on the same situation” (Moscardo, 1996) - a potentially useful trait in a would-be scientist. The suggestion is that mindful individuals are able to
effectively process and question information and feel empowered to recall and learn from interpretation, albeit according to their own agenda (Bell & Gray, 2007).

As discussed in the Introduction, a greater use of science heroes has been proposed as one of many solutions to a decline in university science enrolments seen across many developed countries since the 1980s. Many reasons for the decline have been proposed along with many solutions, including revisions to the science curriculum ensuring the introduction of more interesting practical work and functional examples of greater relevance to young people (Cerini, Murray, & Reiss, 2003); the expansion and improvement to informal learning experiences such as those provided by science outreach programs, museums and other out-of-school science activities (Institute of Museum and Library Services, 2009; Bevan et al, 2010) and the creation of a ‘third space’ in science education, serving as an intermediary between the informal sector and the formal school system, that acknowledges the importance of intrinsically motivated learning experiences (Stocklmayer, Rennie, & Gilbert, 2010).

Scientists and science communicators may have a direct role to play in these experiences. Rennie (2013) argues that effective science and technology communication in informal environments is dependent on a productive two-way interaction between the source of science information and the intended audience. The audience has considerable power in this interaction because people can choose to engage, or not, with the science information that is available. As Trench and Bucchi point out, however, communication about science also takes place between various publics without the involvement of scientists at all (Trench & Bucchi, 2010). Consequently, the scientists of today may be no more able to control the interpretation of science than was T.H. Huxley, as described by McLaughlin (2003), able to control workers’ views of Darwinian evolution in the 1880s.

In Negotiating Public Resistance To Engagement in Science and Technology, Orthia (2013) describes four broad categories of meaning for science: a secular,
rational belief system, an empirical, statistics-based method of inquiry, a cultural institution like art or music, and a source of new technologies. Orthia outlines a range of positive and negative aspects of the four categories of meaning, and some reasons for liking and disliking science; these hint at the deep personal responses people may have but are by no means an exhaustive list. Such categories are directly relevant to this study, which is concerned primarily with how individuals develop ideas about science and their experiences of it.

Ultimately though, all individuals operate within a broader social context in which science (and prevailing narratives about it) must compete for attention, for support and for legitimacy in order to thrive. How science positions itself and what this means for individuals is therefore a subject worthy of further exploration.

2.8 Framing science: positioning individuals as spokespeople for science

The Introduction described a variety of public programs in which scientists have been engaged to appear as talent, role models or science heroes in order to attract and engage public audiences.

There is a number of key drivers for continued public communication by scientists, including economic, utilitarian, democratic, cultural and social factors (quoted in Stocklmayer, Gore, & Bryant, 2001, p. ix). Such rationalisations position the communication roles of scientists as beneficial, contributing to positive outcomes for society. Scholars such as Searle (2013) have also identified benefits for scientists themselves: a 2011 study of Australian scientists revealed that many scientists engaging in communication activities with the public feel positive emotional benefits. As she states: “...these feelings cannot be ignored as they strike at the very heart of why many people choose to become, and remain scientists.” (Searle, 2013; p.51)
Scientists play a role in increasing the public support for science, through political communication about issues they feel may have an impact on the community and lobbying directly for the policy and economic support required to address those issues. For example, the Wentworth Group of Concerned Scientists represents a small, multidisciplinary network of domain experts in Australia who have declared a mandate to link science with public policy and engage in active and deliberative communication to achieve their goals (Wentworth Group, 2014). Others see the ability to work effectively with both administrators and elected officials as a reality of contemporary science and a long term investment (Madsen, 2007).

In some democracies, science ministers are drawn from the ranks of senior scientific experts of the nation, and have a high degree of scientific literacy (Doherty, 2001); in others, any Member of Parliament may potentially have the responsibility, and few are likely to have science qualifications. As science writer Toss Gascoigne observed of the Australian Parliament:

“Few Parliamentarians understand the possibilities of science. They do not understand the limitations of science, or the long time scales it can take to develop an idea into something that will benefit the community. Nor do our scientists understand the work of members of Parliament. They do not have a clear idea of the political processes. They do not appreciate the pressures or the time scales Parliamentarians work to. Both sides, the scientists and the Parliamentarians recognise the importance of each other. But there is no natural dialogue between the two sides, because they come from different worlds.” (Gascoigne, 2007)

One solution for this is an annual Science Meets Parliament event, funded by the Australian Government and Australia’s peak body for science, which invites several hundred scientists to the national parliament. Here they are given briefings about the working of government and science policy, provided opportunities to engage with Members of Parliament and encouraged to practice their lobbying and communication skills (Gascoigne, 2007).
Nobel Laureate Peter Doherty has also observed that direct lobbying by scientists may be beneficial in terms of raising the profile of worthwhile science projects, recommending personal relationships be forged with individual politicians who have responsibilities for science (Doherty, 2001). Indeed, persuasion of British parliamentarians to boost funding for both science and communication is thought to have been a motivation behind Bodmer’s influential report, The Public Understanding of Science (Miller, 2001).

Communication is a crucial part of the scientific process, and without it new knowledge production and research uptake could not occur. Lawrence (2006) argues that three major changes have transformed the context of communicating about research: the shift by governments globally towards evidence-based policy-making; technological change creating new methods for publishing, distributing and sharing material; and the changing nature of government, which has trended towards an increased focus on outcomes, effectiveness and deliverable products. It could be argued that other factors also have an impact: the emergence of globally complex, cross-disciplinary research fields such as climate change science, for example, which require far greater research communication, translation and knowledge brokering (Olsen, Borlaug, Klikkou, Lyall, & Yearley, 2013).

Scientists’ communication has also been linked to economic growth, suggesting that it can help to recruit and develop a scientifically and technologically skilled workforce and hence drive future innovation and economic growth (Russell, 2010).

Individuals within scientific and research communities participate in their specialised research fields through communities of practice and epistemic communities (Moodyson, 2008). Actively sharing information and ideas about research is a key behaviour of scientists within these networks (Cole, Buckler, Creech, & Willard, 2001). For individual researchers, a strong publication record is a key determinant of funding success (Palmer & Schibeci, 2014), but it is by no means the only one. Development of a professional reputation for domain
expertise is also important, and as previously discussed, to achieve this requires active promotion by the individual of their knowledge and abilities, both within their immediate networks and beyond them.

There is, therefore, a range of incentives and motivations for scientists to position themselves as science heroes, which play out in a variety of social, economic, political and cultural forums.

2.9 What role do science heroes play?

For some students, forming positive interpersonal relationships with scientists can play a crucial and positive role in their personal attitudes, decision-making and behaviour in relation to science (Aschbacher, Li, & Roth, 2010). Supporting this view, recent evaluation studies of initiatives involving the direct mentoring of students by scientists indicate that some students show increased personal engagement with scientific subject material, and a change in their personal attitudes and opinions about science (Bouvier & Connors, 2011). Furthermore, research into the values, attitudes and behaviours of young people indicates a close connection between these and their view of science as a future career path (Siegle, Condon & Romey, 2007; Taconis & Kessels, 2009). This suggests that programs seeking to influence these variables using ‘influential others’ as an exemplar have some chance of making an impact on career choices.

However, other research investigating the impact of role models and situational primes on future behaviour suggests that these types of programs may have the opposite effect to that intended (Nelson & Norton, 2005). As previously discussed, role models can actually have negative impacts on student attitudes and performance, depending on the cultural context and type of exemplar used (Cerini, 2010). Observations such as these suggest that such programs require careful development and evaluation, and indicate that much more research is needed to understand all of the effects they may have on their audiences.
It is clear from the literature that many scientists are engaged in a diverse range of public communication activities. It is also clear that many scientists feel passionate about taking part in such activities, but that a number of barriers exist to prevent them from becoming or remaining involved (Searle, 2011). The published data evaluating the success of scientists’ communication activities suggests a number of positive effects; however this data must be treated with caution, particularly in light of the small number of studies available and potential for confirmation bias from researchers who are directly involved in program delivery.

Such communication-related issues are of increasing relevance to governments and organisations globally, as they seek to increase public engagement with science by promoting scientists as public role models and ‘inspirational others’. Simultaneously, the media continues to identify and elevate individuals to the status of science heroes, fulfilling a growing demand for both science and technology-related entertainment and credible spokespeople who can speak convincingly to the rapid global and technological change that has heralded in the 21st century.

Importantly, the questions of how science heroes achieve popular success with public audiences and what they consider to be successful communication remain unanswered, and it is this area of enquiry in which this thesis finds its focus.

2.10 Major research themes and questions

The reviewed literature suggests that individuals’ pathways into science are subjective and personally constructed, but also socially constructed. First-person accounts, such as those of Curie and Lorenz, provide evidence that influential experiences take place over many years and are extremely diverse, including (but almost certainly not limited to): books, family members, lifestyle and daily activities, friends or acquaintances, teachers or mentors, curriculum content, experiments, museums and other places of informal learning, family or social expectations and heroes or inspirational others.
The majority of studies investigating pathways into science have focused on the experiences of young people before they reach significant levels of attainment in science, and these suggest that others including teachers, family and celebrities play an important role in influencing an individual’s career pathways. However, comparative studies of those who have actually attained high levels of achievement or influence in science are rare. An important question, therefore, to ask is:

1: What experiences characterise the science pathways of science heroes?

As depicted in television tropes and as described by scholars such as Hayne, Goethal and Allison, science heroes come in different varieties, and Pinch has suggested that they also use different communication techniques. However, neither the typologies nor the communication techniques of science heroes have been subject to further research. It is useful, therefore to ask:

2: What are the communication characteristics of science heroes, and what can these characteristics tell us about the heroic archetypes of science?

As proposed by Carlyle, the use of hero themes is a universal narrative device used to tell engaging stories that are readily understood, memorable and that convey importance. Heroic stories are useful in science education, to engage students with science topics and communicate the significance of particular achievements or discoveries; indeed, ample evidence exists suggesting heroes are widely used as exemplars in science, with the aim of inspiring interest and modelling achievement. However the norms of science suggest that heroic depictions of scientists may also conflict with established ideals of humility, meaning that heroic stories may not be told as well as they might; sociologists of science, such as Bourdieu and others, describe an inherent conflict between the primacy norm of science and its humility counter-norm. Another important question is therefore:
3: How do the norms of science intersect with communicating about science, and what consequences do they have for those individuals singled out as science heroes?

These research questions informed the design of the research methodology, which is described in detail within the following chapter. There I outline the methods used to answer the research questions, the major decisions made regarding collection and analysis of the data, and key limitations of the study arising from those decisions.
Chapter 3: Methods

3.1 Introduction

In order to answer the research questions, which relate to the individual experiences of science heroes, a qualitative approach to data gathering and analysis was called for.

A qualitative research method was considered most appropriate for this study, considering the challenges associated with researching individuals from a wide range of backgrounds, countries and contexts, the difficulties anticipated in recruiting them and the personal nature of the information being sought from them.

As Flick (2007) has pointed out, within qualitative research fields more than one research perspective is available and in frequent use. A qualitative, person-oriented approach was therefore taken, enabling the personal context for each research subject to become part of the study and aid in the interpretation of their individual responses. This approach avoided the risk of the so-called ecological fallacy – the assumption that the qualities of an individual within the study are the same as the aggregate or average qualities of the entire population (Hermanowicz, 2007).

Not knowing from the outset what information about a person’s life would turn out to be important and what would not, the study sought to capture and examine many aspects of a person’s lived experiences, including their interest and career in science.

Science careers have been the subject of much research, with quantitative approaches widely used to develop broad descriptions of the issues. However, in 2007, sociologist Hermanowicz called for a qualitative, person-oriented study of science careers, in an approach he described as ‘careers in context’. The benefits of this approach, he argued, are in advancing understanding in five major areas of
social progress, namely identity construction, institution building, social-psychological differentiation, job satisfaction and mystification of work (Hermanowicz, 2007). Such person-oriented approaches seek to reveal social processes by examining individually lived experiences; they rely on in-depth enquiry with a relatively small sample of people that is still large enough to reveal within- and between-group processes. Von Eye and Bogat (2006) identified six tenets of person-oriented approaches, including the uniqueness of an individual’s structure and dynamics of behaviour and the need to take many personal and contextual factors and their interactions into account. This approach sees individuals and the larger groups to which they belong as the units of analysis, an approach common in sociological studies that seek to find a balance between individual agency and social group or structural interactions (n.a., 2010).

Thus informed by the literature, I developed a biographical perspective on the study that would enable me to explore the importance of individual experiences, histories and understandings. This informed the design of my research methods, which aimed to capture in-depth personal accounts from a variety of known science heroes. This involved sampling and interviewing individuals and then analysing and contrasting their experiences. Through these methods I hoped to understand the range of processes, experiences, behaviours, skills and practices informing development of a science hero persona. In order to systematically gather information about science heroes I had first to design both an interview protocol and a sampling technique.

3.2 Assumptions within the study design

_Some are born great, some achieve greatness and some have greatness thrust upon ‘em – William Shakespeare (1601)_

Based on the constructed and subjective nature of the term ‘hero’ it was apparent that the timing and processes of becoming a science hero would not necessarily be under the control or necessarily even the awareness of individuals sampled for this study. I assumed that participating individuals might not always be able to
pinpoint specific experiences or moments contributing to their hero status. I therefore determined that a whole-of-life exploration would be a useful approach to interviewing, enabling a wide range of potentially relevant information to be captured. This would necessitate gathering more data rather than less, so I included in the interview design both open-ended primary questions and supplementary questions designed to elicit extended answers and probe for additional information about potentially complex experiences.

Informed by the literature, I also anticipated that an individual’s primacy (being first to achieve particular outcomes) in science would be amongst the reasons why certain individuals might be perceived as science heroes and nominated to the study. This was expected in the case of Nobel Laureates and other pioneering individuals whose achievements are well understood and widely publicised. In such cases, I assumed that these individuals would be well aware of their science hero label and potentially unsurprised to be approached for an interview.

Nevertheless, Merton’s competing scientific norms of primacy and humility suggest that individuals can feel conflicted when asserting their claim to major achievements (Merton, 1957). Under these circumstances, individuals could be expected to have some reservations about being described as a science hero, and might be unwilling or unable to identify reasons for being given that title. In addition, it was apparent that there are many valid and diverse reasons for perceptions of science heroes to develop, and that these may be less than obvious to the heroes themselves. This might be expected particularly in the case of those perceived as role models or distant heroes. In such circumstances, individuals might neither understand nor agree with their nomination for the study. I therefore assumed that there would be a need to provide supporting information when inviting people to participate and in presenting them with background to the research project. Consequently, I developed an introductory letter template that contained supporting information alongside the invitation to participate, and a verbal introduction to the interview protocol that would enable participants to seek further information about their nomination before commencing the interview.
The introductory letter is included at Appendix 1.

The approach described above enabled me to articulate the intentions and ambitions of the study, whilst being mindful of the potentially diverse needs and interests of the interview subjects.

3.3 Analysis

*Neither the life of an individual nor the history of a society can be understood without understanding both.* (Mills, 1959)

A key challenge in this research was to identify a way of answering some fundamental questions about a poorly understood phenomenon. In order to examine the data closely and discern the ideas and patterns present in participants’ accounts, I combined elements of several different qualitative research methods, including grounded theory, narrative analysis and case study research.

A combined approach was appropriate, given key constraints in the gathering of international data. These included limited financial resources that dictated a need to complete the data collection in a single travel period of ten months, during which dozens of interviews would need to be carried out in rapid succession. In addition, the data collection would require visits to numerous cities and towns located on three continents to arrange and attend meetings with the participants. This intensity of data gathering coupled with frequent travel would limit the time available for reflective returning to the literature, which would consequently need to be completed once the data collection was concluded. Therefore grounded theory, which typically requires a constant and iterative journey between data collection and theory genesis, was not an appropriate overall methodology (Birks & Mills, 2011).

However, in completing the analysis I found some elements of grounded theory useful, including comparing the experiences of different participants to one
another and deriving some theoretical ideas from them, returning to the literature for further explanation and clarification in the process. In common with many qualitative studies, I used the coding of interview data to help identify emerging themes and concepts, and used the saturation of themes as a useful cut-off point for detailed analysis of the data. Saturation suggests that a researcher will sooner or later arrive at a point at which new themes cease emerging from the data, while existing themes are consistently reinforced; scholars such as Birks and Mills (2001) have recommended that one should stop collecting data at this point. Using that approach within this study, I have transcribed data in full until saturation has become apparent, and then through selective coding and transcription mined the remaining data for supporting or disconfirming evidence. The legitimacy of the results obtained through this method has then undergone further testing, by contrasting the data from this study with those from other sources.

While narrative analysis methods are often used for comparing in-depth interviews, in this study they have been used sparingly and selectively. The intention behind this study was to achieve both breadth and depth; namely, a broad understanding of the factors influencing and motivating science heroes, and a more detailed investigation of their experiences and communication behaviours. To establish a suitable balance between these at interview required limiting the opportunities for detailed storytelling to a few specific areas of questioning; consequently, narrative analysis has been used selectively on just a subset of the data, where suitable narrative sequences were generated.

Finally, according to Yin (1994), case study methodologies are most useful when trying to answer ‘how?’ questions. In many ways, this study met the criteria by investigating the processes by which science heroes communicate with their audiences, and vice versa. To address this aspect of the study I have therefore used elements of case study methodology, adapted to suit the specific circumstances of the study. Consequently, the study methodology is best described as descriptive and qualitative, using a mixed-methods approach.
3.4 Researcher perspective

In reporting the results of this study, my aim was to be of direct relevance to practitioners and theoreticians in the field of science communication. My decisions about which observations to include were informed by both the literature and my professional views about what is most likely to be useful and interesting at this point in time. In doing so, I have sought to provide the reader with “straight and largely unadorned answers to questions of special relevance” as called for by Sandelowski (2000).

So saying, my perspective on this research has been influenced by nineteen years of immersion in the field of science communication, working within a range of informal learning and science engagement contexts. I recognise the social constructivist bent to my own work, which includes an understanding of the subjective nature of knowledge and a recognition that experiences both in and outside the formal learning environment have an impact on science learning and careers. Whilst I have endeavoured to maintain an objective stance throughout the study, it is always possible that biases and omissions are present; this is particularly true where my own heroes have been included in the study, or my interpretations have been affected by cultural or philosophical biases.

I have therefore given some consideration to both the nature of the researcher-participant relationship and potential interaction effects, which could influence the observed data and its analysis; in addition I have identified the potential for confirmation bias and a number of other methodological issues that can be associated with interviewing. These along with mitigation techniques are summarized below in section 3.15: Limitations and delimitations of the study.

3.5 Ethics

In keeping with Australia’s National Statement on Ethical Conduct in Human Research (2007), all research involving humans is required to have prior approval from a Human Research Ethics Committee. Consequently, this research was
approved by the Australian National University’s Human Research Ethics Committee under protocol number 2008/200. In keeping with the ethics protocol, all participants were provided with an information sheet about the study prior to their participation and advised of the process for withdrawing their data from the study if desired. Participants also completed a consent form authorizing the use of their data for research purposes. Where directly quoted, participants have seen and approved the attribution of their words, or where this was not possible, identifying information has been removed to protect their identity.

A copy of the consent form is attached at Appendix 2.

A copy of the general information sheet is provided at Appendix 3.

3.6 Selection of participants

Overview

The study required the participation of a cohort of people clearly and credibly identified as ‘heroes’. Identification of potential participants was made via a number of steps including personal recommendation, web searches and snowball sampling, which were then verified through a simple triangulation process.

Personal recommendation

Personal recommendations were solicited from a wide range of sources. Friends, family, colleagues and acquaintances were all engaged in discussion about the research topic, and asked for their reflections on and nominations of science and technology heroes. Personal recommendations were also solicited from participants at a range of public and private events where the research topic was presented, including seminars, conferences and public lectures. Proffered names and the major reasons suggested for the nomination were recorded into a database. Around 95 nominees were identified in this process.
Internet searches

The list of nominations was increased through a series of web-based searches using two search engines: Google, which allocates ranking according to popularity, and Yippee (formerly Clusty), which clusters similar entries together and allocates ranking according to cluster size. Key search terms used included ‘scientist’, ‘science’, ‘scientific’ and ‘environment’, ‘technology’, ‘engineering’, ‘mathematics’ or their variants, in combination with ‘hero’ and its variants, and analogous terms such as ‘legend’ and ‘icon’, or their variants. Variants for each term were generated through use of the universal wildcard character, an asterisk (*), appended to the word stem. Examples of the search combinations used include: scienti* hero*, technolog* hero*, math* hero and environment* hero*.

Such searches returned a list of entries, which were then manually checked for content and context. Where content was clearly relevant to the research, names were harvested into a database. Text relating to the nomination of an individual as a hero was analysed and major themes recorded into the database. In some cases, a single entry would reveal a substantial number of nominations; this was the case for a number of public web forums and chat rooms, such as Scienceheroes.com, where people write about and discuss science heroes. A further 86 nominees were identified through this process.

Data verification

Triangulation is a means by which different dimensions of data may be studied, by comparing and contrasting them with other sources (Guion, 2002). To verify nominees to the study, I sought evidence of each individual’s heroic status from more than one source. For each nomination, the individual was subject to further web searching to clarify their identity and field of achievement. In each case, an individual’s identity was checked using a simple name search in the Google search engine. Where numerous possible individual results were returned, or the results were otherwise ambiguous, search results were narrowed by adding
search terms relating to the reason for their nomination, such as field of activity, key achievements, authorship of publications or place of employment.

Once identified, the individual was subject to further searches in combination with the term ‘hero’ and its variants. Returned results were examined for further information supporting a nomination to the study. These reasons were recorded in the database.

**Snowball sampling**

At interview, participants were asked about their own science heroes. Where a named individual was known to be contactable, this name was added to the database. Particular efforts were made to engage these individuals in the interview process, as according to qualitative researchers such as Flick (2007), a major advantage of the snowball sampling technique is that it provides a stronger ‘feel’ and better evidence for qualitative factors, such as the culture within a particular discipline or a school. Seven participants were added through this process.

**3.7 Database development**

The above methods generated 188 suitable nominations, which were managed in a spreadsheet. Names of each individual nominated and the reasons for their nomination were recorded. Reasons were recorded by keyword and notes made where these were complex or ambiguous.

**3.8 Exclusion of data**

A number of the individuals initially nominated to the study and listed in the database were subsequently excluded from it. In some cases, individuals were deceased or it was not possible to accurately identify the individual through online searching, particularly where many different people shared the same name. Exclusions also occurred when an individual’s exact field of endeavour was
unclear, where more than one person sharing the same name in that field was identified as a possible candidate or where the individual did not appear in online records returned by web searching. As the research period and interview budget was limited, potential candidates for interview were excluded if not living in English-speaking, Western democracies known to share a contemporary scientific tradition, specifically Australia, the UK and North America.

3.9 Invitation to participate

Once verified as potential participants in the study, individuals were approached with a formal Invitation to Participate. This required identifying current contact details for each individual. In many cases, due to the scale of their public profile or visibility of their work, the individual’s personal contact details were not directly available. Therefore, enquiries were made through available means, including via their websites, through their institutions or places of work, and through third party knowledge providers such as IMDB, which for a small fee provide contact details for celebrities and media personalities. Once an address for correspondence was identified, an introductory letter headed ‘Invitation to participate: Heroes in Science study’ was sent. With the exception of invitations sent via plain text web interfaces that did not accept attachments, each invitation was issued on university letterhead. The invitation was addressed to the named individual, briefly outlined the context for the study, advised them of their nomination to the study, and made a request for a face-to-face, recorded interview within a specific date range. These date ranges matched a pre-planned schedule for visits to the region in which they resided or worked. The option of interview by telephone at another time of their choosing was also offered.

In approximately two thirds of cases a reply was received, either accepting or refusing the invitation. Where the invitation was accepted, further correspondence took place to arrange a time and place for interview. If no reply was received, the individual was considered to have refused the invitation and no further action was taken to recruit them. In total, 99 people agreed to participate at interview; the number of interviews conducted was slightly less than this, as in
several cases individuals had extremely limited availability and mutually agreeable interview times could not be established within the data collection period.

A copy of the Interviewee List is attached at Appendix 4.

3.10 Interview logistics

The study involved coordinating interviews with many high-profile people, a large proportion of whom are famous, engaged full-time in research, communication or business activities, endure hectic travelling schedules and/or have substantial demands placed on their time, including from students, fans, the media, prospective employers and other researchers. Recognising this, the interviews were arranged to suit the participant’s needs as far as possible, and were subsequently conducted in a wide range of different settings. In most cases, interviews took place during business hours at the participant’s usual place of work. In some cases this place of work was their home, particularly where the individual was self-employed or retired. In some cases interviews took place while either or both parties were in transit, and in these cases a suitable meeting place was identified. These were usually suggested by the participant and included public meeting spaces such as cafes, restaurants and pubs, hired meeting rooms, and private rooms at clubs or organisations to which the participant had an affiliation. A number of interviews also took place by telephone, using commercial Skype Voice-Over-Internet services that enabled low cost calls and video conferencing. In many cases telephone interviews were scheduled for timeslots in between face-to-face meetings, and often occurred with the interviewer and interviewee participating from different time zones.

3.11 Interviews

In-depth, semi-structured interviews were used as the primary data collection method. In keeping with the guidelines set out by Angrosino (2007), these contained pre-determined questions designed to elicit information related to the
specific domains of interest. An interview protocol was developed, covering nine major areas of questioning. Each area was investigated using 2-4 specific questions, with an open-ended design that would facilitate conversation and encourage detailed answers to be provided. The protocol was developed by drawing on forensic interview methodology, which seeks to minimize interviewer effects and encourages complete revelation before further probing of specific issues. A number of open-ended, supplementary questions were designed to encourage further expansion of answers as part of the interview protocol.

The interview protocol is attached at Appendix 5.

3.12 Recording of interviews

As noted by Angrosino (2007) successful recording of interviews requires a fair amount of equipment, particularly when a reliable record of the interview is desirable. The interviews were subsequently recorded using a variety of methods. Most face-to-face interviews were video recorded and also voice recorded on separate equipment, providing a level of backup in the event of equipment failure. This proved to be a prudent precaution, with a number of recordings subsequently discovered to have failed at some point during the interview, usually due to battery failure when interviews ran longer than anticipated. Brief notes were also made by hand during the interviews. Telephone interviews were conducted by Skype and recorded using a software plug-in named Call Recorder. As only one level of recording was possible for these interviews, detailed note-taking by hand provided an important second level of backup.

3.13 Testing of methodology

Having been trained as an undergraduate physicist, and therefore thinking that great scientists were close to being gods, the thought of interviewing a scientist used to scare me. I can still remember my first interview. I went in with my list of questions, all of which I had tried out beforehand on my
luckless supervisor. And, to be quite frank, when it came to the real interview I was terrible... (Pinch, 1992)

Aiming to avoid an experience like Pinch’s, before the study commenced both the research methodology and interview protocol were subject to pilot testing. This required implementing an interview scenario very similar to that anticipated for the study. I was able to identify a potential test subject within my peer group who had been nominated to the study but who did not yet have independent corroboration as a hero, and had not been included in the main interview list. This particular individual enjoyed a growing public profile, as a result of hosting a pilot science television program, making regular public speaking appearances, and writing a science column for a popular magazine. She was clearly establishing a professional science communication-oriented career path, similar to a number of those nominated to the study, but was at an earlier career stage than most.

Subsequently, this candidate was invited to participate in a pilot interview using the process proposed for the study. The interview was arranged for a time and place of her choosing, in this case a home office. The interview was conducted according to the draft interview protocol, and recorded on both video and audio recording equipment. Notes were taken both during the interview and in a subsequent feedback discussion with the interviewee about the recruitment process, interview content and methodology.

This process revealed a number of strengths and important contextual elements within the interview protocol, which subsequently led to the refinement of the protocol and finessing of the interview technique prior to the study formally commencing. These included rewording some questions and statements for greater clarity, identifying elements which could be omitted from the interview if time constraints applied, and developing additional information to be included at interview which would contribute to building rapport with participants. It also revealed and consequently helped me to anticipate some of the many constraints to interviewing, such as interviewer effects, unexpected distractions and
demands, setting up recording equipment in unfamiliar settings, and issues of data and time management.

As the protocol was developed in Australia and tested with an Australian interviewee, it was subsequently also provided to international advisors located in both the UK and USA for refinement prior to interviews there. In each case an advisor provided feedback on local customs and word usage. This helped to ensure that the vocabulary of the interview protocol and meeting arrangements was appropriate and unambiguous throughout. One example is in the wording of the meeting correspondence, which on advice of an advisor changed from ‘put a time in your diary’ (when speaking with Australian interviewees) to ‘scheduling time in your calendar’ (when speaking with US interviewees).

An example of an interview transcript is provided at Appendix 6.

3.14 Analysis

_The trick is to discover essences, and then reveal those essences with sufficient context, yet not become mired trying to include everything that might possibly be described… (Wolcott, 2009)._

The analysis of qualitative data is thought to benefit from the development of a general analytic strategy from the outset (Yin, 2002) and requires a systematic and purposeful approach by the researcher in order to be considered rigorous (Boeije, 2002). The comparison and contrast of information is the essential component of analysis, and is regarded by some researchers as the main intellectual tool of grounded theory (Tesch, 1990) and qualitative data analysis more generally (Sandelowski, 2000). Comparison enables the researcher to identify, code and connect categories of information and answer questions arising from the data effectively and efficiently. It also enables the researcher to describe and conceptualise the variety present within the subject being studied, and can increase both the internal and external validity of the research (Boeije, 2002).
To help achieve a suitable level of rigour within this study, I developed a strategy to guide the systematic analysis of the data. This strategy consisted of several layers of analysis, carried out both within and between data sets. There were two main sets of data generated through the interviews: information about the individual, and information about the sample as a whole. This meant that data could be compared at the level of the individual, both within and between individual reports, and also at the level of the group.

At the level of the individual, handwritten notes taken at the time of each interview were reviewed to identify possible themes and key ideas. For around 50 percent of the interviews, the recording was also transcribed in full and each transcription analysed for key concepts relevant to the individual. A short-form summary of major themes was subsequently developed using key terms or concepts, and the summary was then reviewed for recurrent themes and connecting ideas that might be contextualised by the literature.

At the level of the group, the summaries from different individuals were compared and contrasted, in order to identify recurring themes of relevance across the sample. A bricolage approach similar to that espoused by Gibbs (2007) was used to try and elicit different levels of meaning from the work, including counting instances of key concepts, memoing or taking freeform notes around key concepts, and using contrasts and comparison in order to tease out more complex ideas. As process-level ideas emerged, mindmaps were also generated and later refined using software programs such as CMap tools.

These techniques allowed a wide range of themes at both individual and group level to be identified within the data. The remaining interview recordings could then be reviewed for additional and contrasting examples. Where useful, these sections of the recording were transcribed.

Cross-coding was not used for this study due to the scattered, complex and interwoven nature of the material, which was considered best analysed through thorough scrutiny of interview accounts for nuanced meaning rather solely
through lexicon; as noted by G. W. Ryan and Bernard (2003), such scrutiny-based techniques are ‘unbeatable’ but also time-intensive in requiring much attention to details and nuances. Analysis of emergent themes was further aided by returning to the literature, and where relevant this literature is also cited in the results.

### 3.15 Limitations and delimitations of the study

In endeavouring to address the research questions outlined in Chapter 2, I was required to work within the sorts of limitation typical of most research, including completion within a reasonable timeframe and working with the limited budget and research resources available to me. These factors necessarily restricted what could be achieved, including limiting the amount of data that could be collected, the locations from which data could be obtained and the degree of data analysis undertaken.

In order to increase the ease and consistency of data collection, I imposed limits on the range of data to be gathered. It was clear that many different factors might influence pathways into science and that these might vary between different individuals, social cultures and time periods. In order to reduce the degree of variability in the data across the data set as a whole, the study was therefore limited to include only individuals who were a) living at the time the study commenced, b) English-speakers and c) situated within the traditions of Western science.

Consequently, this is not a global study of the phenomenon of science heroes but a localised one, clearly situated within the time period of the present day and within the social cultures and sub-cultures of Western science, instead of within other forms of knowledge generation, such as indigenous modes of knowing or religious belief systems. As such, it should be regarded as a source of insight into contemporary science heroes within this particular knowledge culture and its associated sub-cultures.
Despite the above restriction there was nevertheless enormous diversity in the dataset, including variation in career fields, which suggests that many different scientific sub-cultures might be represented in the study, and many demographic differences including age, race/ethnicity and gender, suggesting that generational effects such as those described by demographers might be present. In the analysis of results I have not considered these effects or subcultural differences to any great extent, due to the relatively small sample size of different groups within the data and the wide geographical area over which they are spread.

As a solo researcher, I was responsible for gathering, processing, analysing and reporting on data. I therefore sought to ensure that the study design and data collection methods were robust and reliable, which lead to some potential nominations for the study being excluded from the scope, including those that were unverifiable or obtained from unreliable sources, or those derived solely from my own personal experience. Where my own heroes were nominated to the study, care was taken to ensure that they were verified with reliable independent sources as confirmation.

The study set out to identify common themes in the experiences of those nominated as science heroes. Yet despite drawing on a relatively large dataset for a qualitative study of this kind, the sample size still represents less than half of the candidates whose names were nominated to the study, and only a tiny proportion of the total names arising when historical individuals are included. It is likely that, were the sample size to be larger, additional themes could have been identified and, potentially, different weightings may have been given to those identified in the present study.

As Karl Marx noted in *The Eighteenth Brumaire of Louis Bonaparte*:

> Men make their own history, but they do not make it as they please; they do not make it under self-selected circumstances, but under circumstances existing already, given and transmitted from the past.

(Marx, 1852)
According to ethnographic principles, such as those described in Angrosino (2007), stories told by interview subjects of their lived experiences are inextricably embedded in individual histories and social cultures, and should be interpreted as deeply personal and subjective. Nevertheless, whilst each individual is the authoritative source about their own life, this does not guarantee that their recorded accounts are error-free. As Kvale (2007) points out, both interview subjects and interviewers may mishear or misinterpret interview questions and responses, omit information deliberately or unconsciously, make factual errors or provide information that differs from prior accounts and experience a range of effects arising from interactions within the interview, such as presenter effects. In addition, errors of interpretation or meaning may occur in the interview transcription and analysis stages, with nuanced connections or underlying themes not recognised by the researcher.

The use of person-oriented approaches also brings with it a different set of problems and limitations such as those highlighted by Kapila and Lyon (1994). As far as possible, steps were taken in the research methodology to anticipate and address these potential issues. Table 3.1 documents the methodological issues and mitigations strategies used during this study to minimize their effects.

Table 3.1: Summary of methodological issues and mitigating activities

<table>
<thead>
<tr>
<th>METHODOLOGICAL ISSUES*</th>
<th>MITIGATION ACTIVITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Going too quickly may lead to superficiality, relying largely on initial findings and confirming biases, preconceptions and stereotypes</td>
<td>Keep detailed memos and handwritten notes during interviews; Analyse video and audio recordings to provide greater confidence in observations; allow enough time for analysis.</td>
</tr>
<tr>
<td>METHODOLOGICAL ISSUES*</td>
<td>MITIGATION ACTIVITY</td>
</tr>
<tr>
<td>------------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>Desire for statistics and quantitative data</td>
<td>Recognition from the outset that this is a qualitative research project, from which population-level generalisations cannot be made. Where supporting data is required, use robust third-party data sources</td>
</tr>
<tr>
<td>Difficulty in finding the right questions to ask</td>
<td>Develop and test questions prior to commencing study; clearly identify research themes; ask broad, open-ended questions that enable a range of themes to emerge.</td>
</tr>
<tr>
<td>Difficulty in finding key informants</td>
<td>Identify informants from a wide range of possible sources (online, literature, social media, personal recommendations); use snowball technique to identify and reach additional informants.</td>
</tr>
<tr>
<td>Making value judgements about others and having too many preconceptions</td>
<td>Develop a consistent interview protocol and a professional standard for accepting, conducting, completing and analysing all interviews.</td>
</tr>
<tr>
<td>Guiding interviewees with leading questions so as to gain predetermined answers</td>
<td>Use forensic interview techniques which allow for open-ended responses as far as possible; probe interviewee responses in more detail after interviewee has completed story</td>
</tr>
<tr>
<td>METHODOLOGICAL ISSUES*</td>
<td>MITIGATION ACTIVITY</td>
</tr>
<tr>
<td>------------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>Interviewer effects caused by gender and age mismatch between interviewer and interviewee</td>
<td>Take potential gender effects into consideration when analysing results. Apply a consistent interview protocol and a professional standard for accepting, conducting, completing and analysing all interviews.</td>
</tr>
<tr>
<td>Premature closure during analysis of themes</td>
<td>Use multiple theme-identification techniques appropriate to rich, complex narratives to maximise exposure of themes</td>
</tr>
</tbody>
</table>

*Modified from Kapila and Lyon (1994) and Ryan and Bernard (2003)

### 3.16 Summary

This chapter has outlined the methods used in this study and the reasons they were adopted. The choice of qualitative research methods was most appropriate, given the focus of the research questions and the detailed nature of the data to be gathered. The general method was applied consistently across a large qualitative data set, and the data gathered was supplemented from the literature and other contemporaneous sources to improve confidence in the overall findings. Limitations to the study design and methods have also been described, which clearly situate the research in the contemporary cultures of Western science.

The following chapters report the results of this method, primarily the main themes emerging from interviews and key sentiments expressed by participants in the study. Personal reflections, where appropriate and relevant, are clearly marked within the text.
Chapter 4: Reaching for the stars – Key influencers of science heroes.

Some advice: keep the flame of curiosity and wonderment alive... That is the well from which we scientists draw our nourishment and energy. – Michio Kaku (2014)

4.1 Chapter overview

This chapter provides an overview of the findings with regards to the first research question: what experiences characterise the science pathways of science heroes? It begins with a brief characterisation of the science heroes’ response to being approached for interview, before moving on to an in-depth exploration of the key influences suggested in their accounts.

As this chapter will show, questioning in regards to key influences elicited a broad range of responses, which varied with individuals’ personal experiences of being drawn towards and into science. While many of these responses related to people, events, learning environments and other experiential factors, some also revealed important ideas about the nature of science itself. It is the former that are considered in most detail within this chapter. Where pertinent, the latter are explored more fully within Chapter 6, which considers the norms of science as these relate to science heroes.

In this chapter, the focus is on experiential factors found to have influenced pathways into science, which include early childhood experiences, family upbringing and inherited value systems, the presence of opportunities to acquire and practice scientific skills in and outside of formal learning environments, the presence of intrinsic and external motivators, and the importance of ‘inspirational others’ encountered and located in a range of different contexts. To provide evidence, depth and context for my findings, I have included quotations extracted both from the interviews and other data sources.
One consequence of extracting quotes from such a rich data source is that the accounts given are often highly nuanced. As such, they frequently offer more than one theme for discussion, which I have tried to capture succinctly within the chapter’s structure. Where necessary for clarity, I have edited the quotes to remove repetition and oddities of speech that obscure rather than clarify the point. Where possible, I have endeavoured to let the participants’ voices ‘speak for themselves’ in order that the richness of their lived experiences shine through.

Due to the high degree of career diversity apparent within the cohort, the questions at interview were open-ended; although all participants were recognised as science heroes of one sort or another, it was apparent through background research and from the interviews themselves that individuals’ career trajectories, occupational focus and areas of achievement were quite different. For example, at the time of interview not all of the science heroes were practicing scientists and a subset had never worked as scientists at all. Whilst some were research scientists, their specific areas of focus were diverse and included institutional research, science management, governance and administration. Some were busily working at early, mid or late career stage, while others were retirees.

Of the latter, a proportion still remained closely involved in science-related pursuits, such as mentoring younger generations of scientists or reviewing and writing up research material, while others had retired to enjoy non-science-related pursuits. Some were employed in the public sector while others were working for private industry, or in some cases a combination of both. Some had pursued positions in allied fields such as science communication or broadcasting, environmental activism or education, while some were entrepreneurs or working within innovation-related industries. In short, the diversity in the sample suggested that a wide variety of ways of thinking about success could be expected, and indeed this is what was observed within their responses.
Participants were also asked a number of questions designed to discover whom their own living science heroes were and, where possible, these individuals were then invited to participate. It was hoped that use of this snowball approach would provide a stronger ‘feel’ and better evidence for qualitative factors within the particular professional subcultures in which people were located. Subsequently, small groups of individuals were identified who were connected with one other. For example, astronomers Sir Patrick Moore, Lord (Martin) Rees and Chris Lintott were part of one small ‘heroic’ cluster based in the UK. Similarly, Gerry Wasserburg, Larry Edwards and Wallace Broecker together formed an Earth science cluster based in North America.

**Privacy considerations**

A number of participants expressed strong personal opinions about the nature and practices of science, based on their specific career experiences. In some cases, participants shared very negative and even pejorative views of particular events, people, institutions and workplace cultures. Some of these accounts are documented within this chapter, as exemplars of the lived experiences reported at interview. However, for reporting purposes the focus is on the substantive issues raised or suggested by these accounts. Where personal views have been particularly forthright or critical, the people, fields and institutions involved are de-identified in order to protect their privacy and respect the principles of ‘do no harm’ recommended by (Kvale, 2007) and (Flick, 2007). The accompanying text clearly identifies where such editing has occurred.

**4.2 The concept of science heroes and its acceptability**

Heroes by definition hold a privileged position in others’ eyes and it was initially hoped that all those accepting an invitation to participate in the study would be comfortable with the title. However, it soon became clear that some of those participating at interview were not entirely comfortable with being cast as a science hero. Reactions to the title were usually expressed very early on in the
interviews, as participants asked for further information about the study and their role in it.

There were four common reactions to being nominated to the study, which can best be described as happy acceptance, uncomfortable acceptance, refutation and rejection. A number of key attitudes appeared to inform these reactions, as follows:

**Happy accepters** were those who did not query the reasons for their nomination to the study and appeared accepting of the idea that others perceived them in a heroic light. Those in this category tended to be well known for making key discoveries or achievements that had been publicly acclaimed as ground-breaking and/or important, as was the case with many of the Nobel Laureates and inventors. Happy acceptors also included those who had spent a great deal of time in the public eye and were experienced science communicators, such as those employed as television or radio presenters, and those who had held very senior or highly esteemed science leadership positions, such as the role of Chief Scientist or directorships of major public science institutions.

**Uncomfortable accepters** were those who expressed minor concerns about being nominated to the study. Some expressed discomfort at the idea of being singled out in their field, or felt that others were more (or at least equally) worthy of the title. Others queried whether their work was really significant enough to warrant inclusion, or felt that if their work was not in pure science, they should not really be considered ‘science’ heroes. Their concerns were generally allayed after a brief discussion about the processes underlying nomination to the study. Notably, this category included both those who appeared genuinely modest about their achievements or contributions, and those whose expressions of modesty appeared to be more social than genuine.

**Refuters** were those who agreed to be interviewed but at interview, actively disputed the reasons for their nomination. Issues they raised included feeling as though they had not made any notable impact on or been particularly inspiring
of others, not being ‘representative’ of their field, feeling that they were being singled out above other people who were more deserving of praise, and/or feeling that their work, while interesting and important to them, was ‘not significant enough’. This category of individual required more information about why they had been nominated in order to feel comfortable. Their concerns were allayed through detailed discussions about the context of the study, the role of heroes and the sources of nominations. There was a sense from many in this category that they did not want to ‘big note’ themselves. This category was comprised mainly of mid-to-late career scientists.

**Rejectors** were those who responded cautiously to the invitation to participate and after further consideration, decided not to take part. Only one individual clearly fitted into this category; a former college administrator, who expressed a view that his contribution to science was insignificant and that he had “nothing of importance” to say.

In summary, when individuals expressed discomfort with being nominated as a science hero, their concerns appeared to be focused in several key areas: concern about being singled out from the group, concern about their own contribution not being significant enough to warrant the use of the term ‘hero’ and concern about being elevated above others whom they judged either as being ‘more worthy’ of the title or as a potential source of criticism.

Such concerns may reflect sensitivity to prevailing cultural norms of modesty. However, they may also reflect a conflict between differing communication norms identified within science, which as previously discussed include a tension between individualistic and collegial portrayals of science. Being nominated as a science hero undoubtedly placed individuals in the position of feeling singled out or distinguished from others in their field. As the results now described show, the reasons for this are complex – and sensitivity to being labelled a ‘hero’ is entirely understandable.
4.3 Characterising science heroes

The fact that the general public think I’m a scientist doesn’t bother me, as long as it’s a beneficent thing. Because... if I am making them think science is bad then I’m failing in my job. But if I’m making them think that science is ok, and I represent science to them, I don’t care.

(James Burke, television presenter)

Burke’s comment at interview reveals an important aspect of the study: that value as a science hero lies entirely in the eye of the beholder. Despite the nominees being experientially very diverse, the reasons for being nominated to the study could be categorized by a surprisingly small number of attributes, namely:

- Achieving something particularly important, impressive, exciting or unique.

- Being a source of personal or professional inspiration, enlightenment and/or encouragement.

- Making a significant contribution to society.

In short, from the perspective of the outside world, the science heroes appeared to offer knowledge, inspiration and/or achievement. Indeed, those nominated to the study were all high achievers, of one sort or another. Most were award-winning scientists, acclaimed inventors or well-known communicators, who had received substantial media coverage and professional and public accolades for their achievements.

Notably, a proportion of those nominated were not trained or working in science per se but had become synonymous with scientific achievement due to their occupations or public personae. Examples included Ian Kiernan, a builder who founded the conservation campaign *Clean Up Australia*; Rory Stear and Katherine Pearson, business partners in the self-sufficient technology firm, Freeplay Energy
Group; Howard Bennett, a teacher and recreational swimmer who initiated the clean up of polluted waterways in Santa Monica Bay; and the two Mythbusters, Adam Savage and Jamie Hyneman, special effects experts in the film industry whose qualifications were in fine arts and industrial design.

Nevertheless, all those nominated to the study were subject matter experts possessing high levels of domain expertise, as evidenced by their professional skills and credentials, status within organisations, reputation for expertise within particular fields, and strong publication or public speaking history.

Whilst most interviewees were career specialists in a specific field, a number of participants were generalists displaying expertise in more than one domain. This was particularly so for those working in communication-related fields requiring broad domain expertise, such as the science broadcasters David Attenborough, Kathy Sykes, James Burke, Karl Kruszelnicki and Robyn Williams.

In a number of cases, interviewees had gained scientific expertise in a particular field before moving between disciplines or into professional roles requiring a broader range of expertise – for example, individuals working in cross-disciplinary fields, such as the human development specialist Fraser Mustard and the ethnobotanist Mark Plotkin, and those who had played prominent roles in science communication and education, including former astronaut Kathy Sullivan, the chemist and Nobel laureate Harry Kroto, the astronomer Neil deGrasse Tyson and the physician Robert Winston.

Within the interview cohort a subset was also observed of experts who had moved into strongly activist roles, largely with an environmental communication focus – these included David Suzuki (conservationist and former geneticist), Tony Juniper (former zoologist and Friends Of the Earth director), Helen Caldicott (anti-nuclear campaigner and former pediatrician), and Tim Flannery (climate activist and former palaeontologist).
4.4 ‘Ever since I remember’: early interest in science

I think I was always interested in science as early as I can remember. I don't think it was due to my parents...But I did confide to my mother, I said, "You know by the time I grow up everything would have been discovered." She said, "Don't you worry! When you grow up there will be plenty left for you to discover." Francis Crick (1989)

Crick’s comment speaks volumes about the potential roles played by parents in supporting the self-image of young scientists and in assuaging their anxieties about an unknown future. Yet it also speaks of something far bigger: the unseen and, in many cases, unspoken role of entire families – those cultural and social units within which individuals are first situated, in which they develop their earliest experiences of the world and begin to understand their place within it.

Developmental psychologists such as Lev Vygotsky (1962) and Jean Piaget (1969), in writing about children’s development in family environments, have claimed that it is through the lens of the family that we might understand the whole human experience; indeed, constructivist theories suggest that as individuals, our schema for understanding the world are both fitted to and modified by our early experiences of living in it. For most of us, important years are spent learning and growing up within the context of our families.

At interview, participants were asked to describe their reasons for following a pathway into science and encouraged to expand on their feelings and experiences. In response, many interviewees identified having a ‘family’, ‘childhood’, ‘early’ or ‘lifelong’ interest in science, while others expressed the sentiment of having been interested in it “ever since I can remember”. Such individuals may perhaps best be described as ‘science kids’ – those for whom an interest in science apparently pre-dated any conscious memory of specific events or experiences, as well as those whose home lives were populated with memorable, specific science-related sources of inspiration, information and skill.
For some, science appeared to ‘run in the family’; that is, there was a clear sense of a family lineage in which sequential generations had pursued the same or related fields. For example, pathologist and Nobel Laureate Robin Warren recalled that medicine formed an important part of his family culture spanning several generations. Not only did blood relatives precede him into medicine, the concept of being a doctor was an integral part of the career values inherent within his family life:

I always wanted to be a doctor... My mother's family are all doctors. She'd always wanted to be a doctor... she never tried to push me. But that was what I always wanted to do. I think partly because her brother, her younger brother was a doctor and I certainly liked the work he seemed to be doing....

Although not explicitly stated, one gains an impression from this account of available role models, in the form of the uncle and mother, and conversations about medicine taking place naturally within the family context. In this family environment, it appeared that a career path into medical science was perceived as having premium value.

Other participants recalled growing up in families where science-based careers were a tradition. In some cases, they were quite literally immersed in scientific environments, with a number of medical researchers commenting on early exposure to hospital environments. For example, as the epidemiologist, Fiona Stanley said:

My dad was a basic scientist, he was one of Australia’s first virologists. We were brought up, we lived in an infectious disease hospital setting when I was a youngster, just down the road from the Prince Henry Hospital, which was the infectious disease hospital...but it was one that was based in research.

Other participants also specifically recalled a culture of scientific discussion and inquiry forming part of their normal interactions with other family members. As
Gustav Nossal, the youngest of four brothers, recounted of the scientific influences within his family:

One of them was my eldest brother... he was a biochemist, he got a very good position... Often he would come across from Adelaide to Sydney for the ANZAS conference. Not infrequently bringing one or two colleagues... And then my Dad, who was great fun and loved an argument, would sit them down over dinner or after dinner and cross-examine each of them and what they were doing. One might be a physiologist, my brother was a biochemist, the third might be a bacteriologist, and that got them talking about their stuff. I was much younger, I was seven years younger, and it got me incredibly excited. Very, very excited.

The impression here is of a family atmosphere characterized by intellectual dynamism, where curiosity and achievement were valued and where the competitiveness and importance of work at the forefront of science was clearly visible. There is also a strong suggestion of role modelling and inspiration emanating from the older brother who, already well-established in his career, could be seen as the embodiment of a successful scientist. Together, Nossal’s brother and his colleagues can also be seen to form a powerful cohort of ‘inspirational others’ that was available to the younger man and that even after many decades, had left a positive impression upon him.

The power of parents

When I was a child my father was doing his PhD in biology and had a love of nature, and that was always something I enjoyed too. I used to go out with him and run around and help him do his research... The love my father had for science was very apparent, and so from the age of two or three I grew to love it the same way. Brian Schmidt (2001)

Echoing Schmidt’s account, some participants in the study saw having scientific parents as a key influence, in many cases describing how the interests and
occupations of their parents had created a culture of science engagement within their day-to-day family life. In some cases, parents appeared to have been very science-interested and, frequently, shared their interests with their progeny. In one pertinent example, the physicist and broadcaster, Heinz Wolff recalled:

I had a father who had wanted to be a chemist when he was a child... and had accumulated a schoolboy’s chemical laboratory, which would send any health and safety person totally barmy. His parents were against it... (but) he was so keen on it, he actually ran away from home for a bit, and eventually his parents gave in... When I was a small child, he still had all his laboratory equipment. From the age of four on Sundays we did chemistry... I always had colour sets and batteries and so on. I got these things as toys and became manually quite adept. My parents were not particularly safety conscious, I suppose - I’m sometimes amazed that I was allowed to repair electrical appliances at a very early age... So I never actually imagined that I would do anything else. There is alleged to be a family occasion... when I was about four. I suppose my father or my mother said, 'he wants to be a chemist'. I'm alleged to have said 'I'm not only chemical but I'm also technical!'.

Wolff’s account is interesting in that it suggests that his strong sense of personal identity associated with science was present from a very young age, aided and abetted by his parents who provided both opportunities for learning and guidance in the basics of chemistry. Similarly, the inventor Trevor Baylis recalled of learning at his father’s knee:

When I was a youngster my father had a Meccano set which he gave to me. And by the age of 4 or 5 I could do the most amazing things with my Meccano set, and yet I couldn’t write my name. I knew the difference between a nut, bolt, screw and washer. My father taught me how to put things together, so I used to play... I’d make all sorts of stuff... I’d made my first diesel engine by the time I was 12, out of scrap metal, I used to use the
lathe and machine all the bits that I wanted...he used to show me how to use things; he taught me.

In some cases, individuals grew up in physical environments where they were, quite literally, immersed in their parents’ profession. For example, as the doctor Hugh Montgomery recalled:

I come from a medical family. My mother was a paediatric nurse and my father was a paediatrician so I suppose I was always around hospitals and people who worked there from being very young. Certainly in those days hospital doctors and nurses worked ridiculous hours so there was this immense sense of community that people were very supportive of one another and getting on with a job which they believed to be important... Certainly medicine seemed to me to be exciting and interesting...My dad was on duty I think 24 hours a day, seven days a week for pretty much the first seven years of my life. We couldn't actually leave an area around the hospital. I think we had a three-mile radius which took us to a few places and then yeah, so when he was called in I was often sitting on the ward when he was doing ward rounds.

Many others, however, described their ‘non-scientific’ parents as key influencers; they felt that their parents had had an important influence on them more generally, by providing support and encouragement or through contributing specific skills that were useful to the individual’s later success both within and outside the scientific domain. Astronomer Bryan Gaensler, for example, recalled his parents’ supportive attitude and how their interests and skills had helped to get him hooked on science:

My parents were very supportive. My mother is a maths teacher and my father hasn't been to university but he repaired electronics and was an electronic geek and I grew up with all those kits as a kid. And so he encouraged me to build circuits and motors and all the rest of it. And I got my mathematical bent from my mother, she encouraged it...
For a few individuals, parents were regarded as having played a very significant role as personal heroes and near role models. One example of a parent that was cast explicitly in this light was David Suzuki’s father, who had spent countless hours with his son instilling critical communication skills and knowledge, to which Suzuki later attributed his success. Of him, Suzuki said:

My father was my great mentor and hero...(he) created me, basically.

Similarly, neuroscientist Larry Farwell recalled the significance of the relationship he had enjoyed with his father:

I really admired my dad. I think that that was one of the reasons that I got involved in science from an early age, that I saw somebody that I really admired as a person and I saw that he made a difference in the world and that he was the kind of person I could see myself being and he was a scientist.

For such individuals, parents were a source of authority and instruction, as well as models for the specific behaviours and skills associated with a successful career.

For some parents, however, science was clearly not the preferred choice of career for their offspring. Some interviewees recalled having to manage their parents’ expectations that they would choose a different path. As the UK’s former Chief Scientist Robert May, whose mother came from a long lineage of medical doctors whilst his father was both a brilliant barrister and an absentee figure, recalled:

I was consistently told by the careers adviser that I should do law...and my family wanted me to do medicine. And I was not particularly keen on either law or medicine, for personal reasons...it would have been a traumatic event for my mother if I had become a lawyer...and so I chose to do chemical engineering.

A sense of compromise is detectable in May’s account, based on the idea that he had to balance both his own desires and those of his family in settling on a
science path. The suggestion is that May’s choice, while perhaps not as prestigious as medicine in the eyes of his family, still remained compatible with his family’s general academic expectations.

Others experienced family pressure to stay in certain fields despite wanting to follow their own path. These included David Suzuki, who recalled his parents’ severe reaction to his eventual decision to leave medicine for genetics:

My mother wept for months because she couldn’t understand how I would give up being a medical doctor to become a fruit fly expert.

Such experiences suggest that powerful forces of expectation and obligation can circulate within families, and that this can exert pressure on individuals to follow a pre-determined pathway into or away from science. There is also a notion here of the relative prestige that parents may attach to different fields of endeavour – for May’s family, law and medicine were the desirable fields, while for Suzuki’s family, medicine clearly trumped the biological sciences.

The expectation that one should follow a particular career path affected a number of participants in the study. Some recalled experiencing a broad sense of expectation that they would ‘just do’ science. As science broadcaster Robyn Williams recalled:

You didn’t have a choice; you were just told at the age of 13 or 14 that you were in the scientific stream...my father deemed it and the school deemed it, and that was it.

Despite this, many other interviewees recalled their parents not as gatekeepers to any particular career but as sources of material support and encouragement that ultimately helped facilitate their early entry into the world of science. For example, the oceanographer Sylvia O. Earle remembered her parents having a relaxed attitude towards her self-directed interests and achievement:
I had parents who were willing to let me choose my direction...at a point in history when it was possible for a girl or woman to undertake the kinds of activities I had the joy of participating in. While it was not being encouraged, it wasn't being prohibited, either.

Others recalled their parents having had a very hands-on role in actively assisting them to conduct experiments. Scotland's former Chief Scientist, the microbiologist Anne Glover, shared one recollection of her parents who in this account appear to be deliberately leveraging their child’s science interest:

My parents were incredible – neither of whom were scientists, or had any link with science, but were both very supportive of me... I can remember bringing earthworms into the house and wanting to see how earthworms burrowed because I couldn’t quite understand how, if you didn’t have hands, how could you actually get from the surface down into the earth. How does that work? And my parents actually helped me...They built a little thing for me, with two plates of glass that they put earth in between and put an earth worm on the top with some leaves and we watched it do its business. I think they were as interested as me...

Such accounts help to create a sense of parents closely engaged with their child's learning, deliberately guiding the child's growing science interest and skills.

Other participants similarly recalled their parents both participating in and facilitating research-related activities of their child's own design. For example, palaeontologist Mike Archer described how his mother’s approach directly facilitated his ability to 'do science':

From my mum, I got the support for obsessing about the natural world... My mother was tolerant... and she didn't think of me as weird. You know, when I asked if I could borrow a pot so I could boil up a crow to get a skeleton, she didn’t ask me why I would want to do that...when I came in the house with a snake she didn’t ask me why are you bringing that snake into the house...It wasn’t long before my mother built my rock room for
me. I was probably about 12 or 13 at that point. She was good with a hammer and nails, so she defined a zone of one of the large rooms as my place and she built me cupboards, she built a fibreglass divider. In that refuge, I had my stuff and there I would draw, study, research and nobody challenged it. I just had a lot of fun.

From these latter accounts one gains several distinct impressions. The first is of the parents, whose behaviour suggests tacit support for the curiosity of the child. As willing co-conspirators, the parents allow themselves to be recruited into the scientific process not as instructors but as companions who accompany the child on their learning journey. The second impression is that of a child who is busy enquiring about the world. Despite the presence of parents with superior skills and knowledge, the child recalls driving the inquiry and ‘owning’ the answer. There is a sense here that the children have taken on the role of lead investigators in their own research process, aided quietly by their ‘helpers’, whose true level of knowledge is concealed.

Interestingly, these accounts also reveal something about the child’s behaviour: the tendency to bring live animals into the house, with an urgent need to learn something about them. Although such presentations would conceivably have created an immediate practical and ethical problem for the parents, there seems to be no awareness of this on the part of the child. Rather, the response of the parents is recalled as being supportive, and facilitating the process of obtaining a deeper level of knowledge.

**Resources and the rehearsal of scientific skills**

The above accounts indicate that parents’ practical skills and the provision of tools that might support or underpin a process of enquiry can be a valuable resource when made available to interested young people. Certainly, some interviewees recognised that having the right tools at the right time had a powerful effect. This was certainly the case for inventor Emily Cummins, who
recalled the importance of the practical tools contained within her grandfather’s garden shed:

Whenever we used to visit him he’d invite us down to the shed because we could create products... and we’d have a go at coming up with ideas for trucks and what we could use for wheels, then as we got older we could learn to use the tools, and I learned about the different properties...it was just this kind of thinking out of the box which was such a great skill to have as a kid.

Cummins strongly felt that repeated experimentation in her grandfather’s shed had given her an early start in understanding the basic processes of experimentation, prototyping and design. This played an important role in her later design achievements, which she described as being fundamentally about having the ability to “just solve a problem.”

This early development of scientific skills was also a theme supported by many other accounts. In another example, Fraser Mustard, physician and former thinker-in-residence at the Royal Institution in Australia, recalled how he had developed observation skills as a child in rural Canada, playing in the natural world. It was this, he felt, which had ultimately helped him to pass the examination for and gain admittance to a ‘good school’:

I was in grade 6 in the primary school, in the public education system and my teacher told my father I’d never make it (in the exam)...but I went down to write the exam and then when they interviewed me, they said ‘how does a beaver build its dams?’ Well, I had spent my summers living with my aunt and her children in an isolated part of Ontario, 1000 acres of virgin forest with two lakes and a stream on it. Totally isolated, no television or anything like that, no movie houses you could go to. But there were beavers there. I knew how beavers built their dams and why they built their dams because I got to watch them as a kid...and so I gave them a lecture... It was sort of inherently there, the way I was brought up.
For Mustard this example stood out in his memory as typifying what drew him into science; as he, too, described it “I just like solving problems”. Indeed, early encounters with problems to be solved were commonly reported at interview, with a number of participants recalling how parents encouraged them to ‘just find out’ for themselves. As the astrophysicist, Jocelyn Bell Burnell recalled of being allowed to work with her father in the field:

My father was an architect and he would sometimes take me out to be his surveying assistant. And I'd be standing in stinging nettles holding the pole while he had the theodolite and took height measurements. But going home in the car afterwards he would let me reduce the observations. And he always planned that as we surveyed a field we went round in a circle. So you should end up at the same height as we started. And going home in the car I said 'dad we ended up 10 feet higher than we started' and he said 'no you didn't you've made a mistake!' and he taught me about checking. I must have been 8, 9, 10 and that was a brilliant piece of scientific technique to teach.

4.5 Powerful imaginings: curiosity and other intrinsic motivators

_I have this extraordinary curiosity about all subjects of the natural and human world._ – Ian Hacking (2007)

Emerging from the interviews was a sense of childhoods in which the development of ‘scientific’ skills, including observation, inquiry and experimentation, occurred in combination with the individual’s own interests and preferences.

The latter can be regarded as intrinsic motivators – the personal, internal reasons for individuals making a particular choice or following a course of action (R. M. Ryan & Deci, 2000). In this section, I share some of the intrinsic motivators that were reported at interview, which included curiosity, ability and enjoyment.
Curiosity

Many participants described curiosity as being central to their nature, feeling it to be an intrinsic characteristic that they had experienced and maintained since early childhood. As oceanographer Sylvia O. Earle observed, her pathway into science was a direct consequence of being interested in the natural world:

When I was a little kid, like most little kids I began with a vivid curiosity and when people asked me what I wanted to be, it had to do with plants and animals. And later I understood that meant being a scientist, being a biologist and it was a matter of making choices to go in the direction of learning about the natural world – biology, chemistry, geology, maths. Not because someone told me I had to, but because I was attracted to it.

Many others described themselves as inherently curious, ‘just wanting to know’ or ‘always asking questions’ about the things that they encountered around them. As Bryan Gaensler put it:

As a kid I drove my parents crazy... there was this one particular teacher at my school... we are still in touch and when he scores a student that he says reminds him of me and asks him so many questions that he goes cross-eyed and drives him crazy, he gives them my email address...

Such accounts suggest that as children, the participants asked a great many questions out of curiosity. And, as evidenced by Gaensler’s account of his teacher, some children share a similar questioning behaviour. Curiosity was a recurring theme within the interviews, and many participants reported that a strong sense of curiosity and wonder has never left them. As inventor and engineer Tim Hunkin described it:

For whatever reason, I’ve just sort of got a curiosity about the world around me, the man-made things around me...and it’s always very exciting when I realize ‘Oh! I don’t know that that’s made of’ or ‘I don’t know where that comes from’ or ‘I don’t know how that works’...I think a lot of it
just comes from observation...I think that’s what I like. I love all these things that we take for granted really – it’s just so amazing all round, which is true of nature and I get excited by that as well. But I have no interest in contemporary science and quarks and all that…it’s just the stuff I see and play with.

These accounts speak to two important recurring ideas that emerged from the interviews. The first is that some individuals have a persistent, underlying curiosity about the world and a passion for the things that they are interested in. In his expression of delight and excitement in the things that he sees around him, Hunkin demonstrates some of the powerful emotional factors that may be at play.

The second idea is that of the individual deliberately pursuing and reinforcing their interests through the choices that they make. In Earle's case, her interests create a vision of her potential future career path and inform her decisions about which subjects to study. In Hunkin's there is a sense of choosing the more interesting and exciting things around him; man-made things ‘just excite him’ and he explores them through open-ended, self-guided exploration, or play.

**When curiosity meets opportunity**

For some participants, their recollections of upbringing were characterized by continual exposure to science-related learning that was general rather than specific in nature. For example, as the virologist George Poste recalled of growing up in an agricultural community in rural England:

> There was always a very active dialogue happening in the house about what was happening, what was the implication of the weather, what was the implication of this affecting such and such a farm, and so forth, one just osmotically took that in. And then one's playground was vast, there was a small cohort of us, male and female, about fifteen of us used to prowl what is the sort of the marsh inlet of the English channel - I grew up in East Sussex, there was so much to be seen there. And the malicious
effects of things like robbing birds nests with ever greater bravado – not ecologically approved of today but one learned a lot in one’s immediate environment...it was a great source of stimulation because of course there wasn’t a great deal else.

In contrast, some participants recalled very specific experiences of play and observation that they felt had had a particularly powerful effect on them in childhood. For example, as Anne Glover recalled:

I would have been probably around about ten...My brother who was five years older than me had just been given a chemistry set and he wasn’t the least bit interested in chemistry. But I can just remember him opening it and playing with it in the kitchen...he was just throwing things together. And inadvertently he created this wonderful explosion. I was over on the other side of the kitchen but I saw that and I thought ‘I don’t know what he’s doing, but whatever it is, that’s for me!’ And I thought, ‘that’s amazing!’ Because he just had lots of tubes of dry stuff and things and he has made this incredible explosion. And I thought ‘how would that happen?’... That’s what set me off and I would have to say, I have never been disappointed.

An interesting aspect of this account is the sense of a ‘Eureka moment’, where Glover experiences a deep connection and moment of joy in discovering the secret knowledge contained within the chemistry set. Similarly, palaeontologist Mike Archer also described a critical moment from his own childhood:

I remember Aunt Edith, who was one of my father’s editors, who came up from New York periodically to review the things he was writing. She knew about me. From New York, she brought up a little box that was just a little square box. The kind you can still buy in shops. And it had about 20 minerals in it with little names on it. I remember that so vividly and touching, feeling, smelling the odd, slightly different smells and that was my introduction to interpretive geology... all I wanted to do was find out what else there was and not only find out all the different sorts of things,
but what they were. So that was the kind of opening of the door into the geological world... that moment definitely sticks in my memory - just being blown away. It’s interesting - I don’t remember any other present I ever received as a kid at Christmas or anything else. I remember that and it eclipsed other things. Why? I don’t know... That one triggered excitement in my brain in the way that nothing else I ever received as a present did. It’s peculiar.

Such examples show that scientific toys or tools can have an exciting and powerful effect on the recipient – and that these effects can be far reaching. In both of these accounts there is a clear suggestion that the child had a sudden awareness that there was *so much more to know* about the world than they had previously realised. Furthermore, this sudden awareness created new and urgent questions for the child, which could be now answered through the tool – providing them with a powerful new way of accessing and knowing about the world.

Overarching or perhaps underpinning these accounts is also a sense of the child’s sheer excitement at the possibilities that are suggested by stepping through the doorway into a mind-boggling, vast new world revealed through extraordinary experiential encounters. In some cases, such experiences made such an impression that they helped to establish a clear sense of future self. As the astrophysicist, Neil deGrasse Tyson recalled of his first visit to the Hayden Planetarium in New York City:

I was nine years old and I saw the night sky projected on the dome, but the way you do it you’re not even thinking that it’s projected, because it’s so real and it’s so there. Growing up in New York City...the sky was not something you had a relationship with. You looked up, you saw streetlights, you saw tall buildings, nobody was thinking sky. I’m nine years old before I see a real sky, except it wasn’t a real sky, it was the planetarium sky and I thought it was a hoax. That’s how much of an urban brain I had. I said, ‘there can’t be this many stars. It’s a nice show you’re
doing here but it’s not real!’...To this day when I see the greatest skies that ever are from mountaintops with telescopes I look up and I say, ‘it reminds me of the Hayden Planetarium’... That’s where it all began and it was cemented when - I think I was 12, 11. A friend of mine handed me a pair of binoculars to use and invited me to look up...I looked up at the moon and the moon was just stunning - mountains, valleys, craters and hills. It was another world. There wasn't just a bigger moon. It was a better moon. I said, ‘this is it, I’m in it’. If you asked me - starting at 12 years old, the perennial adult to kid question, what do you want to be when you grow up? My answer was astrophysicist, from age 12 onward.

DeGrasse Tyson’s account reveals something of the powerful, almost visceral effect that some science experiences can have on the individual, reminiscent of the accounts provided earlier by both Glover and Archer, which also convey a sense of personal transformation and a potential future direction, driven by the individual’s desire to pursue the new knowledge. This sentiment was echoed by the astronomer, Heather Couper who recalled how her own ‘discovery’ had triggered a strong desire to find out more:

At the age of seven or eight I saw a green meteor – it must’ve been about 10:00 or 11:00 – I was looking up into the sky around Heathrow Airport in London, because my dad was an airline pilot. I thought, ‘oh dear. I should go and tell my parents this’ because I shouldn't have been out of bed. I said, ‘mummy, daddy, I’ve seen a green meteor!’ and they said, ‘well, that’s very nice dear, but there are no such things as green meteors’. In one of the main papers the next day, the main national papers, it said, ‘green shooting star seen over West London’. So I said to my parents ‘na, na, na, na, nah. I’ve seen a green shooting star! I want a telescope!’ And that was it.
Powering imagination: the role of books

In a 1989 interview, Sir Francis Crick recalled receiving a gift of the Children's Encyclopedia as a young boy. Rich with detail about how the world works, the book Crick recalled was a key source of inspiration that directly fed his childhood interest and enthusiasm for science. Crick's book was bought for him by his parents, who appear to have recognised and nurtured the nascent science interest apparent in their young son, despite having virtually no interest in science of their own.

Like Crick, a number of science heroes in this study identified books as a key source of their own scientific knowledge and inspiration as children. Whilst reading is a crucial part of any career in science, literacy in early childhood seems to have played a particularly important role in helping some individuals imagine their possible future pathways into science. Now retired and still intent on "catching up on his reading", pathologist and Nobel Laureate Robin Warren described his early experience of books:

I had my own bookcase in my bedroom, which was packed full of books...I was surrounded by books. I love reading, I always have. When I was a kid, the Oxford Junior Encyclopedia was produced; it was about a 12-volume encyclopedia...and as those volumes came out I would read them from cover from cover...I also read lots of scientific books when I was a kid, which I thoroughly enjoyed. I didn't read them because anyone made me...I'd drop in on my Mum on my way home from school and then go around to the bookshop and buy books and have a wonderful time too. That is one thing Mum didn't mind me spending her money on...I bought a whole lot of books on medical history which really inspired me...Fascinating reading about what doctors were like, pretty well back from Egyptian times. And most of it was about doctors from about the last two or three hundred years and how medicine has changed in that time and the fantastic discoveries which were made. I thought that was fantastic...
Warren’s account points to a strong desire and ability to read from a young age and suggests that, unforced, his interest in medicine was supported and stimulated by the reading material that he chose. Similarly, many participants recalled reading biographical novels about inspirational figures, who they felt had played a role in firing their imagination. For example, the physician and anti-nuclear campaigner, Helen Caldicott recalled how reading stories gave her clear ideas about a future path helping others:

I was going to be a teacher, I thought that was good, a way of helping people. But I got into bed one Sunday morning with Mum, I was eleven; I said 'I'm going to be a doctor'. She said 'yeah, why?' I said 'I can help more people'...One of the first stories I ever learned was the Good Samaritan, I used to lie in bed with dad, telling him about that, when I was about four. And Robin Hood was one of my heroes, I read and read and re-read that story as a child...I've just always been incredibly idealistic and altruistic.

Caldicott’s account suggests that her younger self was forging a strong sense of identity reinforced by the messages within the literature. Of note is her desire to ‘read and re-read’, a practice also referenced by many others within the study including the physician, Fiona Stanley, who recalled:

I read Marie Curie when I was about eleven or twelve... And I was inspired by Schweitzer, hero of Africa. A lot of that stuff, which my father encouraged me to read...I read about a guy called George Washington Carver, called the Peanut Man...I got that book out of the library when I was 8. And I was really pleased in the end that the dog chewed the front cover because we had to keep it... That was an inspirational book for me, he was the first black scientist in America, a basic scientist and biochemist.

One interesting feature of the above accounts is, once again, the insights they provide into the supporting role played by parents, whether in enabling unfettered access to libraries and bookstores, providing direction to seek out particular types of literature. There were also many instances of parents
encouraging deeper engagement with the meaning contained within books, as was the case for the Mythbuster, Adam Savage who recalled:

My mother was a librarian and so books were everywhere. And we couldn't just ask a question, it was like we have to brush me up, look it up in the encyclopedia, or whatever it was.

For some, inspiration from literature was not just contained to extending knowledge or imagining future selves; in some cases participants recalled feeling 'their eyes were opened' to the world, and different ways of seeing things. For example, as the broadcaster, Karl Kruszelnicki said:

I remember being a given a picture book about the universe...I was about 7 or 8...it really made me realize how big everything is. I've never lost that feeling of wonder.

Whilst Kruszelnicki's experience occurred as a young boy, for others particular books played an important role in adolescence and young adulthood, when representations of science helped to unlock their understanding of the world. As the broadcaster, Jonathan Sanderson recalled of reading about quantum tunneling as a physics student:

Tony Haye and Patrick Walters wrote a kind of coffee table quantum physics book... And that was amazing, I didn't understand half of it but the pictures were pretty, and then just a couple of bits completely blew my mind, and that was a big hook actually, that I think sometimes it's the individual concepts. They are still some of the best descriptions of what quantum tunnelling is. I can remember it was on the left hand side of the page, halfway down, this little picture, and I can remember reading that, probably very late at night. I remember the little energy curve diagram and the dotted line going straight through the potential barrier and thinking 'how does that work? and I guess it's at that point when you catch yourself asking those questions, that's when you start thinking.
Whilst for Sanderson, this specific depiction of quantum tunneling had him asking ‘how?’ others recalled literature that conveyed a specific sense of science as a practice and its importance to society; for example the Nobel Laureate, Peter Doherty, who commented on his experience of discovering the work of Aldous Huxley:

His writing was the first time I had come across someone talking about science in a literary way – he was talking about society and life with some science in it... I just found it really fascinating.

Many others similarly found inspiration in science fiction writing. As the physician and former Australian of the Year, Ian Frazer observed:

It was a vision for the future and the known and unknowns that I found particularly interesting. It was the sort of science fiction that wrote about plausible futures rather than totally implausible, rather fantasy type stuff.

For some participants, literature not only powerfully captured the imagination but also led to concrete actions, such as solving puzzles or trying out experiments that they had read about. Perhaps the best example of this comes from the physician and Nobel Laureate, Barry Marshall, who recalled realising that he could do the same things as those being described. His memories of specific books and the desire for action he felt they spurred in him were particularly rich and diverse:

When I was about ten or eleven or twelve I started reading novels. And I used to like these biographical novels... I just went right through them. *Thomas Edison* was pretty exciting because I could do things that he did. You know, I’d make a morse code set, so that was an interesting story... I read about the Mayo brothers in a *Reader’s Digest* condensed novel and they were pretty exciting. They used to operate on their puppy, and then they grew up and started the Mayo Clinic... The other one I read was *Brother Surgeons*, which was William and John Hunter. And William Hunter was a bit more studious and academic, and he had a museum and
a surgery up in London, up in Edinburgh. And John Hunter was his rough younger brother, who probably had ADHD or something. Went off to the war, and used to do anatomy, and found out how to cut people's legs off in five seconds. And (he would) often not do amputations because he knew the anatomy. He said 'you don't actually have to cut this one off because the artery's still there'. So he did a lot of important stuff. And he ended up, he self experimented on himself, you know. His theory was that gonorrhea and syphilis were really the one disease. So he infected himself with some gonorrhea, and it just caused a pustule on his arm, I think that's all it was, or maybe he did the real thing. But the story is that he accidentally also infected himself with syphilis. Because he was wrong, it was really two diseases. And the syphilis was silent until he dropped dead and had a massive ruptured aneurism while giving a lecture when he was seventy years old. That's the folklore, I don't know how true that was...So Brother Surgeons is a great story about these two young doctors, young medical students, who dug up bodies for the anatomists and were doing all this stuff in 18th century England. So a pretty exciting story. I had those. And I really just wanted to be a GP... I just thought, wow, I could cut and sew people up, (do) surgery, all that type of thing...

Despite many decades having elapsed, Marshall's recall of the Brother Surgeons is fairly detailed, and what he recalls has some synergies with the career path he would himself later follow. Like John Hunter, Marshall would go on to perform medical self-experimentation, albeit with happier results; in 1984 he swallowed a live culture of H. Pylori to help prove that the bacterium is a leading cause of stomach ulcers. It is unclear from Marshall's account if the adventure in Brother Surgeons had any influence on that decision; however, it is apparent that he was drawn to the adventure and excitement of medicine as described in the books he encountered from an early age.

A number of others recalled specific books being highly influential. The physicist, Lawrence Krauss, who recalled a particularly heroic tale of science encountered whilst in Grammar School, provided this example:
You read about these great scientists...I remember I read a biography of Galileo when I was a kid, in grade 5 or 6. The idea sort of crept in, somehow, it meshed with fighting the forces of evil, trying to convince the world of something that was right and (to) be brave and all the rest... It had all the elements of a classic hero; for me that was a factor. I read about people like that.

Krauss also reported being inspired by the tales of Lawrence of Arabia and in particular felt affinity for ‘those kinds of people who stood out against the crowd’.

Such reports suggest that the heroic representation of scientists in literature, where they are cast as adventurers, risk-takers, life-savers or the first to achieve, is highly memorable. Krauss’ account also suggests that the depiction of the scientist as a hero, as someone working against the odds to make a difference, helped to build ideas of identity in science to which he could aspire.

While such dramatized accounts of scientists’ lives were an important influence, textbooks were another category of literature recalled by interviewees. For some readers, textbooks provided a key to unlocking or understanding the mysterious features of the natural world in evidence all around them. As Mike Archer recalled, a textbook painstakingly procured with his pocket-money facilitated new knowledge, and with it, great excitement for the material:

For me, it was just coincidental. It was an event that happened 10,000 years ago. There were glaciers that sort of stormed down out of Canada and all through the area I lived, they dropped rocks that belonged in the rest of the world as the glaciers melted. So our backyards were filled with what to the other people and the farmers in the area were a bloody nuisance. You know, they had to farm around them. Suddenly, I’m seeing a rock with a funny looking thing in it and that was a pretty powerful trigger. That happened when I was about 11. So the obsession really began pre-teens, well pre-teens. I didn’t know what these things were. I didn’t even know what a living brachiopod was and here was a rock that was
filled with extinct forms that were 20 times as diverse as the living brachiopods. I spent my allowance, as little as it was, in buying books...I bought the classic - the bible for me was Shimer and Shrock’s *Index Fossils of North America*. It was that thick, had a blue cover and it was fascinating. Boy, I memorised every page in that. It was an atlas of all of the prehistoric creatures known from North America. With this book, which took about a year and a half’s worth of allowance - all of a sudden I could start to identify them and understand what these things were that I was finding in the rocks.

Engineer and inventor Stephen Steiner was also enthralled by a textbook, in this case about molecules:

> My favourite book in high school was The Merck Index. It’s thicker than a dictionary, it's (about) a bunch of molecules and you just read about how they’re made and what they do and what their names are and you look at their structure. Sometimes they have pictures... Or encyclopedias. I always love encyclopedias, just paging through... And you can be selective, you could pick up stuff that was interesting and ignore stuff that’s boring.

Steiner’s account highlights the ‘dipping in’ or ad hoc nature of reading for pleasure, and portrays an individual seeking out material pertinent to his own particular interests, discarding whatever isn’t interesting or doesn’t capture the imagination. Indeed, for some participants, short and highly consumable forms of non-fiction were recalled as being important sources of inspiration, such as the serial magazines *Look & Learn* and *New Scientist*. As Ian Frazer said of the latter:

> I got Issue 1, Number 1 given to me at school when I was about 10 or 11, and provided every week. Just reading the popular science that was described in that was very inspiring.

From such accounts, an impression is gained of individuals using literature of all sorts to follow their own interests, gaining enjoyment and empowerment through selectively reading about and digging deeper into the things that most interested
them. In addition, one gains the impression that books, in feeding the individual’s curiosity and in some cases also inspiring them to action, helped them to make better sense of their world.

**Enjoyment**

*Science is fun. Science is curiosity... It’s delving in.* – Sally Ride (1999)

Former astronaut Sally Ride’s opinion of science as ‘being fun’ appears to be shared by a vast majority of people taking part in the study, regardless of the stage they were at in their science careers when participating.

Many people reported feeling a strong, motivating sense of enjoyment from their science experiences, which usually started from a young age. In some cases there was a sense of both physical pleasure and mental stimulation. As computer scientist Sue Black described it:

> I really liked mathematics. I loved mathematics at school and when I was thinking about what I wanted to study after that, then maths was a natural choice... I think it kind of tickles my brain in all the right places. I don’t like every single bit of mathematics, so it’s not all maths but some things just really, I don’t know, just give my brain a real buzz... It makes me think of, you know when you listen to a really lovely piece of piano music? My brain gets the same...you know that kind of tingly feeling? Not all the time, but now and again you’d get that moment and it’s amazing.

Other participants suggested that the enjoyment they had experienced from science in childhood, of curiosity rewarded when trying to figure out ‘how and why’, had carried over into their adulthood. This was the case with Stephen Steiner, who recalled:

> I am still a kid. It’s a state of mind more than anything. I love to imagine things and I love to create things, I love making stuff. When I was really little...I’d try to make my own video games out of cardboard boxes and
straws and tape... the first geeky thing that I really got into was computer programming because I love video games, I love Nintendo, I had a Gameboy... and I really wanted to make my own video games and it was like: How do you do that? I got introduced into computer programming that way. Fourth grade is when I started picking it up, and I was interested.

Steiner’s account suggests that his childhood worlds of play and experimentation fed his interest in programming. There is also a strong suggestion that his adult world of science is still informed by the playful and inquisitive approach that he finds so enjoyable. This sentiment, of adult practice informed by childhood play or experimentation was echoed by many others in the study. In some cases participants felt that the ongoing ability to problem-solve, visualize and build things in three dimensions was related to this early pastime. For example, the chemist and Nobel Laureate Rudy Marcus recalled:

I had various erector sets and I played with that set so much...I always liked mathematics. That kind of structural approach and so on. I visualize things a lot...I don't draw well, but I like drawing things, the visual sort of thing. I think the sort of construction – the mathematics, the construction of mathematics - I think that plays a role in what I do. Like in the rewriting of student papers, the structure of the whole thing. In thinking through some problem. The structure in there. Often you don't do things necessarily in the most logical way, but you sort of feel that this may be the answer then you explore it. It's not as though you go rigorously from A to B to C to D or anything like that, but it's sort of feeling and jumping. But then you have to fill it in. The whole structure - the arrangement of things - the building of an argument, the derivation of something, is something that may be related to some of those earlier things in childhood...there were tinker toys and erector sets and Meccano sets.

Marcus’ account proposes that the ‘trial and error’ approaches he developed in childhood through mechanical play have had some bearing on the exploratory approaches that he would later use in order to identify and refine structural
problems. Similarly, the Mythbuster and special effects engineer, Jamie Hyneman recurred of his early approaches to solving problems:

I discovered that the way to solve, to come up with a solution to the problems, the physical challenge of making something move in a particular way or whatever...I had to be able to internalize all the elements at hand and visualize them. And I got into a habit of it. I have a specific place in my head like a room that I go into, it has characteristics in it like any room does and I go into that room, and every time I go in I rebuild that room... I start to assemble all the things I need to consider, and build them in. And I walk around, and it's sort of an exercise in visualization. And through that process of forcing myself to completely become absorbed in that world, I am able to embrace the problem and see things in their totality as opposed to a random collection of data, or facts... And once you capture that totality, then you've got control of the thing and you can pull a cog out there and insert something else, and see that something that happened way over there that you didn't want.

Hyneman's account is suggestive of somebody mastering the art of visualizing solutions to mechanical problems, based on many years of practical experience in hands-on assembly; indeed, at interview Hyneman expressed that both his enjoyment in science and grasp of the physics at play in his televised experiments were continually improving, with each one feeding the other. To paraphrase, he felt that ‘the more I know, the hungrier I get’, and at interview both he and fellow Mythbuster Adam Savage enthused about their continuing curiosity and delight in figuring out how things work, and their often simultaneous solution-finding in the midst of experimental design.

Hyneman recalled growing up in a farming community, where myriad practical problems continually presented themselves as requiring solution. In contrast, Savage recalled living in an urban environment where his artist father encouraged experimental play that was both rich and deep:
I took apart everything I could get my hands on: radios, televisions, stereos, machines, watches, clocks; I've been playing with building things since forever, my father was an artist so I was always very encouraged to do that... to just try whatever I wanted to try...and I always had the ability to use my dad's charge account at the hardware store, which I realise now is probably one of the single greatest gifts I would have had. At the age of 11 I could walk round to the hardware store and get whatever I wanted.

In contrast to such accounts of physical play and exploration leading to greater curiosity, skills and understanding, some participants recalled being thrilled by the discovery of new concepts depicted rather than enacted. For example, concepts presented to them within non-practical environments, including in classroom lessons or in television programs. As the physics educator, Laura Grant described of her enjoyment in learning:

I always liked science. I always liked it. When I was at school I was always interested. I always asked loads of questions and it was something like sort of working things out and problem solving and logic and stuff. It was satisfying to me to be able to understand how something worked...I wasn't the kind of person that took apart radios or anything... just the different bonds between molecules or why some things are hard and some things aren't or what's a magnet or just weird questions like that I was always quite interested in... when the Open University programs used to be on, I used to watch stuff like that. I had no idea what it meant but I'd just be like, oh what can it mean? All these little patterns of diagrams of molecules and stuff. It was always a bit of a mystery to me. I thought it was quite interesting.

Grant’s statement portrays a young person who is deeply interested in the material and gains great enjoyment from consuming it, seeking out experiences that would further build and reinforce her knowledge. Indeed, within the interview cohort many other sources of inspiration became apparent.
For some it was ‘collections of things’ that formed a source of inspiration. As the biologist, Nancy Rothwell put it:

There were always bits of bones and things at home, and books... I have very early memories of pickled fish in a jar that I was fascinated by, or seeing skeletons and how they worked - so I guess it was all mammalian biology. I was always fascinated by that. I could have happily pulled them all apart and had a closer look.

Like Rothwell, many other participants reported feeling a strong sense of enjoyment from informal science learning, especially when it was self-guided and free from the constraints of everyday life. For many, it was ‘an outlet’ that delivered experiences that became a crucial part of their growing up. For example, as the inventor, Trevor Baylis recalled:

During the war I used to collect rubbish... one day I went to this house and this lady said ‘I’ve got a box that you can go and take to the scrapyard’... and on the way back I was intrigued to see what was in this box. And it turned out to be an enormous Meccano set. So I nicked it! Took it back home. And then of course I could do anything I wanted to, with my mates. So all of sudden I became a mechanical engineer... in those days you could buy any kind of chemical you like, no matter how old you were. We used to make fireworks, bangers and god knows what...we used to put lumps of sodium down the drain in the street and watch the lid blow open – that was our idea of fun. That was part of growing up. We could do so much.

Indeed, a sense of learning science through informal play and self-guided experimentation was a concept woven through many people’s accounts at interview. One particularly poignant account came from David Suzuki, who recalled of his difficult teenage years:

My great thing was a swamp that was about ten minutes away by bike. You could just bike up to the swamp and collect insects and fish, all that sort of thing. So that to me was my great joy and outlet. I was an insect collector
as a kid, I was an avid fisherman. I toyed with being an entomologist or ichthyologist, but I knew I was going to go into some aspect of science.

From such accounts one gains a sense of the pure enjoyment in science experienced as a child, which cemented by opportunities to use the ‘real tools’ of science created a strong sense of empowerment. In one example, the palaeontologist and former arts student, Tim Flannery spoke of how practical experience gained at a museum had been crucial to his future career path:

I went to a school where it was hard for me to flourish in the areas I wanted to flourish in. I suppose the pivotal, big break came for me when I started volunteering at the Museum of Victoria...a very young American curator then, by the name of Tom Rich sort of took me under his wing and said 'why don't you clean up these fossils and do this and do that'. So I was doing an arts degree...and volunteering one or two days a week when I could, and cleaning up these fossil kangaroo skeletons from a place called Morwell, that turned out was a new species of Kangaroo. It was an amazing fossil because the stomach contents were preserved, the leather and the follicle patterns of the skin were preserved, there was mats of fur, incredible things, little foetuses, or pouch young, in the pouch and Tom said 'why don't you just write a Master's at Monash, just describe them' because he was a professor at Monash too. So I did my Master's there.

Flannery also recalled that he had always just ‘had it in his brain’ that he wanted to be a scientist of some sort. As he said: “I don't think I really seriously entertained any other career.”

Such accounts again suggest the power of practical exposure to career futures. In another relevant example, the astronomer Patrick Moore recalled:

I lived in the East counties and opposite us was a big estate run by a man named Hambrey. He grew orchids, and also had a small private observatory called Brockhurst Observatory, run by an astronomer called WS Franks... he showed me how to observe, I was about 10, then... and
then Franks died, and Hambrey said to me, I was then 14, ‘well, he’s gone. Would you run my observatory for me?’ So I found myself running the observatory when I was 14, and I did that until the war when Hambrey died and it was broken up.

Moore’s experience of being given real responsibility created a strong sense of pride and identity, which he would also go on to foster in others. Later becoming famous for providing young people with access to similar opportunities as those he had himself enjoyed, Moore stated of the countless visitors to the telescope housed in his garden:

It gives me great pleasure to meet people who actually began by coming to see me or watching one of my programs. For example I remember I heard from a ten year old boy I had met at a school: please can I come and see through your telescope. Which he did that night and the next night. And now he’s director of a very big observatory. So that was good fun, and there’s plenty of those around.

Moore’s account suggests that he knew of other astronomers who started out by gaining practical experience in his home observatory. Examples included the astrophysicist Chris Lintott, who Moore recalled had come to visit whilst in his teens and ended up “a far better astronomer than I could ever be”. At interview, Lintott himself would reflect on the combination of interests, practical exposure and ‘big ideas’ that had made a difference to him, reporting:

It started with astronomy... I was a kid with binoculars and a telescope, and then around the time I went to secondary school, with the school having this fantastic observatory and letting us use it, I think that crystallised some of it, around the time that you're deciding what sort of thing you want to end up doing. That was the catalyst, and the idea that it wasn’t all done yet. Somebody, at some point, said to me ‘and we don't know’, meaning we, the human race, doesn’t know, and at about the age of 12 that was quite a powerful idea...for me it was always the fact that there are ideas to be played with.
Half a world away another astrophysicist, Bryan Gaensler, would also reflect on the impact of a real world experience encountered as part of a high school excursion – in this case not to an observatory, but to the Chemistry Department of Sydney University:

In year 11 we did x-ray crystallography of some crystal and we brought home all of the chart recordings...and in class we went through how you do x-ray crystallography and how you work out what sort of crystal it is. And that was really amazing, to actually get to use real equipment, not some dumbed down example or idealized system but real equipment to do some simple experiment and actually understand at least the basic version of the measurement. I think that was an incredible moment for all of us, I mean it wasn't a great discovery or something that no one had ever done but instead of reading something out of the book, or doing some very simple experiment, we were using real data.

From Gaensler’s account, an impression is created of motivation and empowerment stemming from the realization that this was ‘real science’. Gaensler, who already enjoyed physics, suggested that a difference had been made to his sense of capability and knowledge, which further fired and stimulated his enjoyment.

A sense of science as intrinsically ‘fun’ was also apparent in many accounts participants gave of the reward they derived in their professional lives. As Earth scientist Wally Broecker said of his discovery of the ocean’s ‘conveyor belt’ system:

I had one good idea and almost every other aspect of it turned out to be wrong, but the central idea was right. Everything’s got adjusted as time goes on, because you learn more. One thing leads you on to another, and on and on. But you guess at a lot of things and your original guesses are wrong. But that’s why science is fun. Also it’s a huge challenge to beat the earth out of its secrets...it’s tough to figure some of these things out. You
get great joy out of it, finally it occurs to you, my God, this is the way it is!
I’ve had a lot of that, where I was the first one to realize something. I don’t
know if it’s a competition but it’s nice to be the first one to think of
something...

Broecker equated fun of science with a sense being in competition with others,
and this was one of several different aspects often cited at interview as being
particularly enjoyable. Some individuals appeared highly motivated by the ‘game’
of science and its challenging problem-solving aspects. As Barry Marshall put it:

When I got into medicine, then I realised there was a very interesting
intellectual problem-solving part of it... it was like an Agatha Christie
novel. If you could put the clues in the right place, you could connect it all
back to one illness. So you might have five different things the patient’s
telling you, and some weird signs. But if you know your stuff, you can say,
well one disease actually explains this, this, this, this and this. And that
was the joy of medicine for me.

Others were drawn to a vision of science as source of a future adventurous,
outward-facing life; as former astronaut Kathy Sullivan explained:

I started college as a language and linguistic major and then discovered
the sciences, a pattern of life I really was looking for - an adventurous kind
of life and a chance to get out and experience and know the natural,
physical world - but also the cultural and geographic; the World - writ
large, what this place of ours is.

Sullivan’s words convey strong ideas of a personal identity that both pre-exists
and is reinforced by the potential glimpsed within a possible future in science – a
future life characterized by adventure, experience, knowledge and exposure to
the world. Importantly, it suggests that her younger self had seen in a science
future something exciting, ambitious and deeply satisfying – enough to answer
her hunger for more and switch track part way through her studies.
From these accounts, it is clear that enjoyment in science can come from a number of different sources, including the feelings of autonomy and self-discovery, the challenge of problem solving, experiences of awe and wonder, the mastery of knowledge and the thrill of competition. Enjoyment also appeared to manifest for individuals at different key stages of life, depending on the previous experiences and predispositions of the individual.

**Capability**

From the interviews a consistent picture emerged of individuals developing, from a young age, capabilities and skills that could facilitate future pathways into scientific careers. Behaviours that fitted into this category included asking questions, finding out about things through processes of observation and experimentation, collecting and categorizing things, and the discussion and solving of problems.

Nevertheless, within the study sample participants’ views of their own natural aptitude for science varied enormously. Some distinguished having an innate interest and ability in ‘doing’ science from the degree of interest or ability they had in performing well inside their formal science education. For many, the latter was not something that they perceived as coming naturally to them, nor always achieved with ease. Rather, it was something that they had to work hard at during their school and university years. As marine chemist Bill Fenical described:

> I kind of liked science things but I wasn’t a strong student at all. I was interested in football and life... and I started thinking of going to college when I was in high school. I didn’t have a great record (but) I had a good enough record to get into college. And then things started to change for me. My advisor told me that I should be a forest ranger; I was that kind of kid. I just liked what I was doing and I realized that every ounce of school you could get was extremely valuable for the future. You couldn't just
avoid school and have an exciting career... From that point on I took it upon myself to make things happen, but the motivation wasn’t very high.

Others spoke of having a natural ability at science subjects that ‘just made it easy’ to continue on that course. Some of these said that they felt a great sense of ease and clarity about the subject material that helped them to excel. For example, as mathematician and broadcaster Adam Spencer recounted:

I’m really lucky with mathematics, because it makes such implicit sense to me... I just did it right from the start. I could see things numerical, I never had to cram into my head that 7 times 3 is 21; it’s just obvious to me that if you’ve got 7 dots and 3 dots making a rectangle, there’s 21 dots there. That’s just the definition of multiplication for me... I was probably about half way through third year at uni before I really encountered mathematics that didn’t make sense...

For some individuals, a pathway into science was just a matter of utility; certain science subjects they found provided the least barrier to progressing through their schooling with ease. For example, as physicist and science teacher Averil MacDonald recalled:

I was one of those annoying kids who was good at anything and everything. I could easily have gone in any direction, I found all the subjects easy. Another reason for doing physics was that the homework was shorter; solving a numerical problem, you know when it is finished, you put it away, you do something else; writing an essay you can go on forever, tweaking and word changing...same with doing translations...No, I thought, this is it: you know when you’re right or wrong and then you can put it away and go and do something more interesting... It was just the pragmatic thing; I had everything (else) I wanted to do, alongside schoolwork. I hated doing homework...
From such accounts, a concept emerges of individuals weighing their natural interests and abilities against the realities of needing to make progress along a pathway through education, and from there out into the ‘real world’ of work.

**Ambition**

A number of interviewees spoke of their personal drive and motivation to progress in life through a pursuit of science. Many reported having experienced moments of anxiety about their abilities and interests, or having encountered significant obstacles to proceeding, such as a difficult childhood, impoverished family upbringings or a disconnected schooling experience. Despite these, some were sufficiently compelled by their desire to achieve something of importance that they pursued the 'high road' into science.

Geochemist Gerry Wasserburg, for example, recalled being introduced to the study of mineralogy and crystals during a troublesome childhood, when he realized for the first time that there was “something in nature that was regular, and very beautiful”. This love of the material, he said, had carried him forward for most of his career. He also recalled his ambition to pursue further study after returning from active service in the Second World War:

> Everything just reappeared again after the war...I had not graduated high school when I went into the army. When I got out I had this piece of paper saying I had a lot of experience in outdoor living. I would do well in a road crew or working in a forest service. I decided that was a hell of way to spend the rest of my life...

Wasserburg was motivated, compelled and ambitious enough to continue on to college despite his lack of qualifications and a need to learn, almost from scratch, all of the mathematical skills required.

For other individuals, the ambition they felt appeared to be a more significant driving influence than confidence in their underlying ability necessarily was. As
computer scientist Sue Black explained, of returning to study whilst a young parent:

I think determination is a really big factor. I think you have to be reasonably intelligent but determination is actually more important because if you’re intelligent and not determined you won’t get anywhere...I really want to achieve things in my life so when I decide to do something I really go for it. I’m quite ambitious, so I’m thinking about where do I want to be next year? Where do I want to be in 5 years time?... I’m quite often thinking about what I’m doing now fitting in with what I want to do... I’ve always had that kind of mentality, I think. If I want to do something I just get on and do it rather than waiting around for something. Because you never know what might happen, really.

Black, too, would persevere on her path, despite feeling intimidated by the adult learning environment through which she was ultimately able to re-enter science.

Others discussed feeling uncertainty about what pathway they were on and why, particularly during their high school or early university years when many possible options presented themselves. For some of these individuals, the ambition to make their mark seems to have outweighed any uncertainty they felt. As Lawrence Krauss recalled of his high school science experience:

The thing that I remember being worried about a lot was being disconnected from humanity, from social things... (but) the thought, the possibility of being the first person to know something was what kept me going through it all.

In this account, Krauss suggests that his teenaged self had an awareness of something fundamental that science had to offer – the possibility of primacy. He attributes this possibility with a motivational power that exceeded his fear of possible detachment from society. From this we catch a glimpse of the aspirational vision Krauss had for himself: being somebody who might succeed, by being the first to discover something. Such aspirations – to persevere, achieve
and to be first – appear as powerful driving forces for the individual; powerful enough, at any rate, to keep them heading down a pathway into science.

4.6 ‘They made me do it’: extrinsic motivators and pressure points

When I was a kid, I had two role models. The first was Einstein, whose futile search for a theory of everything fascinated me. But I also watched the old Flash Gordon series on TV. I was hooked by all that I saw...Eventually I realised that what was driving the entire series was physics. So I saw that my two loves as a child were really the same thing. – Michio Kaku (2014)

At interview, a number of participants described external forces that they felt had encouraged or demanded them to succeed in science. The motivating factors they reported included social experiences, family expectations, the pressure of competition from peers and the instructions of careers advisors and teachers.

Science and the peer group

Krauss’ earlier account of his teenaged anxieties speaks volumes about the importance of social factors in the decision-making of individuals. Unsurprisingly, social influences were observed at many different stages for individuals within the study, with many observing that their peer group influenced aspects of their science performance and attitudes towards their science studies.

Some participants recalled the importance of participating in a social context, where feelings of engagement and belonging were the most significant factor in their experiences of learning science. As science broadcaster Rob Morrison described of being held back a year during his high school education:

Suddenly I was with people my own age, who shared my interests, and that was when school became happy for me, the last two years of it. And
suddenly I joined in clubs and societies and we had a science club and I went along to those things - and it was as much the camaraderie with the people I was doing it with, as the subject matter. So that had a lot to do with social development, when you’re getting on with friends, whatever you do is interesting. So that was good.

Others reported that social competition and reinforcement played an important part in strengthening their interest in science. Gustav Nossal, for example, recalled being part of a small study group of like-minded peers, which created a pleasurable learning environment in which new skills were developed and individual interests, knowledge and prowess were reinforced:

We were six hundred in first year med. We quickly slimmed down to three hundred in second year ... it was pretty harsh climate. We weren't very well taught, the classes were too big, the number of professors too small. In third year we started teaching each other. We were the sort of group of so-called clever kids, we found each other and we started reading our stuff up in the library and then giving each other mini research seminars. Now that got me very excited and that I think was the beginning of me wanting to do research myself.

Others recalled close friendships that formed a key part of their experiences of engaging with science both in and outside formal learning. As biologist and broadcaster Aubrey Manning recalled:

What really got me tuned into the natural world was at the beginning of the war, we moved out to Surrey to a new estate...I woke up aged 9 and outside my house was fields and a stream. Quite soon afterwards, on my scout trips, a friend and I began working towards our naturalists' badge and we were keeping a nature diary and I became utterly fascinated by the birds...the thing was, there was no biology taught in my school so I couldn’t do biology for state exams. Then we got a new headmaster who was a botanist and he wanted to teach biology at the school and there were two of us who switched into biology. So I had the most fantastic
experience. We sat in this study, the two of us, doing a crash course in biology, and I totally latched onto that.

For others, peer influence and connections provided opportunities to strengthen or further direct their interests into science. For example, the astrophysicist and Nobel laureate John Mather recalled a key decision in his scientific career that was strongly influenced by a friend:

I had a friend who was in graduate school at Berkeley. He sent me a picture of himself sitting on a fountain in short-sleeve shirts in January. I thought ‘oh, it’s really nice in Berkeley’. He said, ‘why don’t you come out here and get a summer job?’ I think he even sent me an application. So I did. I went out there for my summer job, and I really liked it. I changed my plan and decided to go there for graduate school instead of Princeton where I was planning to go. Because of that sort of random and not particularly memorable thing, my life is all different.

One can imagine how powerful the social and emotional factors may have been in drawing Mather back to Berkeley; for a young man facing choices about which new city would be his home, the opportunities and connections of established friendships and professional networks would no doubt have been compelling.

Other participants recalled how the peer group informed an understanding of their relative success within science. As broadcaster Robyn Williams recalled of being stuck on the ‘science track’ despite his interests in the humanities:

By the time you get to 18 or 19 in that kind of system...that’s it, you’re only qualified to do one thing, and that is to continue with science, which I did, and along the way it struck me that it was probably a good idea, because of the various arts things I was doing anyway, in my spare time. So if I was to do anything at university, studying science was a good challenge because otherwise I would never do anything like it. I had several friends who were doing science as well so it might have been something of a struggle – because the people who seemed to be doing really well at
science had the most formidable command of it. I’m talking about the physical sciences. So I opted for biology...

Williams’ decision to take biology seems informed in part by his perceptions of others’ abilities and his likely chance of success relative to others in his peer group. The decision, as it turned out, was a happy one; in the late 1950s, just as Williams was making his decisions, the work of pioneers such as Watson and Crick had begun to place biological science in the ascendant; as Williams later said “I didn’t know it then but...it had become one of the most exciting areas”.

Williams’ account underscores the sense some participants conveyed of having ‘just falling into’ science, following a pathway that lead through secondary school and on to university, where the talents of more experienced people would help to galvanize their interests. For example, as the author Matt Ridley said of his experience as a bird-watcher before entering the world of university:

It became a sort of obsession in my teenage years, mainly I think to get away from life! But then suddenly it turned into 'gosh, I would love to do this at university’. I wanted to do zoology, et cetera... I’m not passionate about science at this point, I’m just passionate about biology and natural history and then to arrive at Oxford and the whole sort of Neo-Darwinist selfish gene thing is just breaking and you get sucked into this incredibly fresh way of seeing the world, and it lights you up and you get very excited about it. Then it dawned on me that there is no more spectacularly wonderful thing than to eavesdrop on the minting of new knowledge. Who would want to do anything else in their life than be hanging around people who are finding things out that have never been found out before?

However, peer groups also had a powerful reverse effect on some interviewees, who described how the difficulties of social interaction actually led them to retreat into the ‘easier’ world of science. As Tim Flannery recalled of his teenage years:
I was pretty unhappy at school, I didn’t like the boys’ environment or the religious environment there. So for me, once you dived into the waters of Port Philip Bay, that was freedom. So I had a snorkel and flippers and you were in a totally different world...the great fascination for me was this extinct world...to find a whole whale's jaw, a fossilized whale jaw, or the tooth of a shark, you know a tooth that big, all of this amazing stuff, buck teeth of giant extinct marsupials that washed in, that was much more interesting to me than the modern bay. The ancient bay must have been something much richer and more interesting...the imagination of that past world was always important, I suppose, to me...I collected lots and lots of fossils, which I gave by and large to the Museum of Victoria when I went to uni.

Similarly, the palaeontologist Mike Archer recalled of his ‘escape’ into the natural world:

I guess as a kid I was probably socially inept. I didn’t relate to other kids at all... In that period for me came animals, rocks, the natural parts of the Earth. It was easier to relate to them. They weren’t judgmental, they weren’t critical, they weren’t playing games with you, they weren’t bullying, they weren’t wanting to know what football team you supported. These were things that had an intrinsic story to tell me about the earth and I just found those more interesting things to relate to. So I think in many ways, when I brought back a willingness to integrate with people - probably in my mid-teens - it came along with the stuff of the earth. It came along with a natural part of the world. That was then part of my personality and ‘love me, love my rocks’, you know... I’d have to say it was girls who brought me out of that reverie. But I didn’t leave any of the fascination, the obsession with the natural world behind. It came with me. In fact, if a girl wanted to spend time with me, she had to share my cacti collection and all sorts of other things, you know. I was fairly inclusive in all of that kind of stuff.
In both of these accounts there is a tangible sense of separation from the peer group, and an impression of young people craving experiences beyond those on offer in their social worlds. For both Flannery and Archer there is a sense of exploring a natural world characterized by compelling stories and hidden knowledge.

In Archer’s case, this vividly contrasts with his sense of discomfort at the mundane, messy and uncertain social interactions that surrounded him. There is also a sense that Archer’s interest in science formed a crucial part of his teenaged identity, by which time he was already certain about the importance of the natural world in his life and had apparently integrated his passion for it into a concept of who he was. Importantly, he believed that others must accept that too: it made him different, but he was able to take confidence from that. So armed, he successfully negotiated his way as a young adult through the world of social interactions.

Archer’s sense of otherness seems informed by having interests that lay outside the mundane and inexplicable world of his peers, a separation that ultimately he was able to reconcile through an expanded engagement with the world. Other interviewees also had a keen sense of otherness but felt they had less power over it, particularly when it was thrust upon them unwillingly by factors beyond their control. This was the case for Suzuki, whose Japanese heritage had caused his family to be interned and relocated during the Second World War. For him, self-guided observations of nature in the swamps and fields of his childhood became his “great salvation”; they were a place in which his sense of identity was able to develop, despite a painful sense of separation from his peers.

Other forms of dislocation were also reported by interviewees, most notably in their younger years. These included prolonged illness suffered during childhood, which took some individuals out of school for long or recurring periods. For some of these people, such as Nossal, the process of resuming normal activities like their school education provided a form of positive reinforcement: as he reported,
illness had brought with it the sensation of missing out and in recovering, he had relished the opportunity to participate again.

These and other accounts given at interview suggest that a sense of identity in science is informed in part through individual interests and pursuits. For some, the sense of being different to or isolated from the peer group changed when they met others more similar to themselves. Archer, for example, also recalled the revelatory experience of attending science fairs and in the process connecting with a group of other youths who were more ‘like him’:

... for me, this was the revenge of the geeks and the nerds. You know, this was where, if you were really interested in things and doing experiments and doing science, as a teenager, all of a sudden, somebody cared...I was suddenly mingling with people who were as nutty as me about things...

Similarly, the astronomer Heather Couper recalled feelings of alienation in her late adolescence that resolved into a sense of belonging, on being welcomed into a community of like-minded people:

I was quite a lonely child, because I was a large person that was not quite into the glamorous girls’ school thing... between when I did my A levels at the age of 18 and when I went to uni when I was 21, I actually was a management trainee for Topshop. I was working in the fashion industry... and I realised then that I wanted to get into astronomy. My mother found an editorial in the local paper that there was a local astronomical society and I contacted the organiser and he took me under his wing. He's still one of my very best friends and his name was Robin Scagell... he actually introduced me to the world of amateur astronomy and then that lead to the springboard of getting into professional astronomy, going to university, doing research and all that.

One gains the impression from such accounts that finding and connecting with a mutually interested peer group can maintain and validate a personal interest in the world of science. But what of the influence wielded by those outside the peer
group – those who are more learned, experienced and well-connected than oneself?

**Familial expectations**

As the earlier accounts show, parents can play a key role in facilitating their children’s interests and skills in science. As some participants also recalled, the desires and cultures of their families created specific expectations that they would continue on in certain study and career paths.

For some, a sense of obligation emanated from their knowledge of the past sacrifices made within the family in order that their own generation flourish. This was particularly true of those growing up during the Second World War and in the immediate post-war years, who expressed an awareness of the sacrifices made by their parents and grandparents in order that the following generation might prosper. Some reflected on the obligations inherent within their family culture, as in this example from Robin Warren, regarding his mother’s sacrifices:

> She actually wanted to be (a doctor) but...her father died and she was brought up by her mother during the Depression and they just didn’t have any money... and the stories she used to tell us about how they were brought up, I don’t know how her younger brother ever went through medical school actually. But apparently her mother used to save up every penny she could and she put her son through medical school. But she couldn’t manage to put her daughters through medical school. I think actually my mother, if she had ever managed to do it, she would have been rather an extraordinary person too...

One gains a sense from this account of the importance medicine holds to Warren’s family and to his mother, in particular. Whilst he does not explicitly explore its impact on his decision to pursue medicine, it seems clear that within the family context there were compelling emotional reasons for him to do so. An interesting aspect of this account is the sense of family folklore that relates to the sacrifices of the previous generation. Warren’s grandmother and mother are in
some ways ‘unsung heroes’ of the tale and their sacrifices are implicitly acknowledged and honoured by the decisions Warren later makes in pursuing a pathway into medicine.

This sense of generational sacrifice was also apparent in other accounts given at interview, where parents were reported as wanting more for their children than they themselves had; for example, as Jocelyn Bell Burnell said of her mother:

> She missed out on university because there was a slump in the linen trade in the Depression and her parents couldn't afford to send her and her brother, so they sent her brother and he wasted the opportunity. She was very keen that her daughters as well as her son got the opportunity, because she had missed out.

Whilst family hopes and expectations are implicit within such accounts others, more explicitly described the impact of pressure from their parents. One such example came from David Suzuki, whose family had suffered greatly during the Second World War as Japanese-Canadian ‘enemy aliens’. As previously reported, Suzuki strongly felt his father had “‘created him’”; that is, had played a critical role in shaping his life and profoundly influencing the person he had become. Suzuki recalled his childhood years, in which his father had tutored him towards success to a very significant extent; as he recalled, every day they would talk about what he had learned at school, and why it was important:

> My father was my great mentor and hero and when I was growing up he would come home from work and every night after dinner he would say ‘so what did you learn today at school?’ I would have to try to remember the lessons and if I said something and he didn’t understand it, he would say ‘I don’t understand it, explain it again’.

Suzuki’s father also instructed him in the specific communication skills he believed were required for his son to succeed at life, including repetitive training in public speaking and oration. From this repeated childhood practice of public
speaking to a high standard, Suzuki felt a life-long habit had developed that later informed his global science communication efforts.

Other individuals were also made aware of the importance of pursuing an academic career because of the esteem placed upon it by members of their family. As marine pharmacist Bill Fenical recalled, his father, who was from a rural family, held a college education in great esteem:

My dad was fresh from high school when he got a job and through his whole career finally worked his way up to what was a junior engineer. But he had a friend who had a bachelor’s degree... he went to college! He had everything going for him...my father thought so highly of him; he kept saying ‘you ought to go to college’ and stuff like that. He didn’t know anything about it, (so) I didn’t have any help applying...

Such accounts suggest that a sense of responsibility or obligation existed for a number of the participants and that this formed part of the context for their decisions regarding the course of their studies. In the case of some participants, family members actively intervened in their education to ensure that they stuck to the ‘correct’ course. For example, as Jocelyn Bell Burnell also recalled:

As soon as we started doing science it became clear I was good at doing it, in particular, physics. I failed a very important exam at the age of 11, and I should have gone on to become a secretary. In the first week there was an announcement that on Wednesday, the boys were to report to such and such a room and the girls to another room. The boys were being sent to the science lab and the girls to the domestic science lab. When my parents heard that, they hit the roof, as did the local GP who had a daughter in my class, as did the parents of another girl. And when the science class convened there were 3 girls and all the rest were boys. And I came top in the exam at the end of that term.

Burnell’s account highlights not just the determination of her parents to see her succeed, but an important recurring theme in the experiences reported by
participants, both male and female: the almost universal presence of encouraging and engaged parents who appeared to have paid close attention to the individual needs, abilities and talents of their offspring. In many cases parents appeared to have played a crucial role in steering their child on to a science track – or away from other, ‘less desirable’ occupations. For instance, as Heather Couper reported:

I’ve just been awarded the CBE ...a lot of that has to rely on citations from well-known people in the public eye, like the Astronomer Royal, people in industry and that kind of thing. ...I just seem to have been taken very seriously and it’s not something I would've, I guess, expected to happen to a little girl of seven, especially in those days when I said to my dad, ‘when I grow up daddy, I want to be a pilot’ and he said, ‘well, that’s not possible dear, because girls can’t become pilots’. I said, ‘well, okay, daddy, I'll be an airhostess’. He said, ‘no, you're not going to be an airhostess, because that's just like being a waitress’. So, two years later I said, ‘daddy, I'm going to become an astronomer’ and that was it.

External competition

Participants’ views on the competitive nature of science are explored in some detail within later chapters. For the present discussion a few key points relating to external competition are particularly pertinent.

For many participants, the competitive nature of science was only regarded as a motivational factor once they had reached professional levels of practice. For others, however, a sense of early achievement in science was clearly galvanized through direct competition with their peers whilst still at school. Stephen Steiner, for instance, described the powerful motivation he felt when he first gained success in some competitive ‘real science’:

In sixth grade we had the option in science class to do extra credit, which a pedantic little student like myself was all about, at that time. So I was
going to do a science project just to get the extra credit and I submitted it and surprisingly I won second place...and it was such a shocker to me. I was like ‘holy crap, really? That’s cool!’ So the next year I was all gung-ho about science... It was such a validating thing because up until then I thought science was super boring... In seventh grade I was really geared up to do science...and I got second place again. The first place winner was the daughter of a real scientist... and in eighth grade I was determined to beat her...so I looked for a project and I came up with a huge parametric study to try to isolate elements. And I did, I got first place and I got to go to the regional science fair.

This sense of competition as a motivational force was a theme recurring in many of the accounts given at interview. For some, it was powerful enough to keep them working in science despite occasional thoughts to the contrary; as Bryan Gaensler recalled:

I can’t guarantee that I’m going to be a scientist for the rest of my life, there are other things I’m interested in...but ultimately it always comes back to the fact it would kill me to decide not to be a scientist and then read about discoveries...it would really tear me up to think I had chosen not to be a part of that. And even though I don’t make every discovery, quite often I read something and think ‘oh I wish I’d done that!’ If I had picked some other career it’d be disappointing to think that other people are getting to live the dream and I had chosen not to.

**Advisors and the mapping of career pathways**

A small number of participants recalled influential experiences of receiving careers advice. For some, such as the broadcaster Adam Hart-Davis, there was a straightforward recommendation to follow a pathway into science issued by a trusted advisor. As he recalled:

I had this amazing maths teacher when I was about 9, 10 or 11 who was brilliant, who was a very, very good teacher. Jack Turner. And I remember
him saying when I left the school, he summoned me...he said ‘Hart-Davis I have one thing to say to you', and I said ‘yes sir?’ and he said ‘Science’!

Some, like Gerry Wasserburg on returning from the army, had not liked the advice they received and had reacted strongly against it. Wasserburg felt that science was where his interests lay, despite the perceptions of his advisors. For him, practical experiences in childhood had revealed something beautiful hidden in the world of crystals and minerals. Presented with a choice about what to do next, he followed a path that could take him back into that world. Others, such as Bill Fenical, recalled that the careers advice they received was positive. For Fenical, who received advice while still at high school, it helped to clarify a possible future direction, which was compatible with what he already enjoyed and where he felt his natural interests lay.

In both of these cases, the advisors seemed to have assessed the interests, aptitudes and experience of the individuals in order to arrive at their advice. And in both cases, the individuals had responded to that assessment, albeit in slightly different ways. At interview, Bill Fenical would reflect on his experience of leading a ground breaking marine chemistry lab at the Scripps Institute in San Diego. On the significance of providing good careers advice, he said:

I am producing the people, and that’s the most important thing: that they reach their career goals. Sometimes I’m a little less enthusiastic about some people, sometimes I’m more enthusiastic about others – you know, there is a human element here. Somebody is just simply not as smart and creative as someone else. I’d rather be positive about them and when they ask me ‘what should I do?’ I tell the great ones: ‘you should go up here’, (and) the others: ‘let’s take a more modest approach. Here’s how you fit, in the spectrum of life and quality and the university’. There’s Harvard and MIT and I send people there... to others I say ‘you know, I don’t think you want to be in those environments, they’re going to be very much out-competing you. Here’s the kind of environment you need to be in, you would be very well qualified here, feel comfortable here, feel very much as
if you are achieving this’... That’s important because (if) people go places, they don’t get tenure, they fail, they end up in a snowball effect down to nothing... You don’t want to be in an environment where you fail.

In his account, Fenical suggests that good advice can help individuals to recognise the strengths and weaknesses of their own capabilities and in doing so help them make decisions about an appropriate direction to take. This appears to be supported by Wasserburg’s own experience of receiving such advice at a later career stage; at interview he recalled an experience of personal careers advice received from an established scientist, who had become an important mentor to him during his undergraduate degree. As he recalled:

He would talk to me about anything... and pushed me to do better things. Finally he came to me, and he said ‘I think you should go to a better school...this is not good enough for you’. I said ‘what else should I do?’ He said ‘study physics, mathematics and chemistry, and then you can do something important in geology’. So that’s what I did.

These reflections from Wasserburg and Fenical suggest that trusted careers advisors have an important role to play in the early stages of a scientific career, particularly as individuals prepare to transition from one level of training into another. From both accounts it appears that trusted advisors and career mentors can have a profound influence on the ideas a young scientist has about themselves. It is therefore to this topic that the discussion now turns.

4.7 Inspirational others and science superheroes

Many interviewees reported that other, usually older and more established people had exerted an important influence on them as they progressed into science. From the accounts given, these ‘influential others’ fell into two key categories: teachers and other academic mentors, and science superstars. Importantly, both of these groups contributed to the individual’s understanding of what science is and their potential role within it. Crucially, they also helped to
generate the workplace characteristics and academic culture that many felt were important to their career progression and satisfaction within their science career.

The role of teachers and academic mentors

Many participants recalled being influenced by particular teachers and academic mentors at different points in their life. The impacts they reported were felt at all stages of learning, commencing in the primary school years, experienced throughout high school and university days and continuing well into the workplace, up until about mid career in some cases.

From the accounts given at interview, the qualities that emerged as being key to the impact of an influential teacher can be categorized as follows: inspiration and enthusiasm, acknowledgement, scaffolded knowledge, practical exposure, talent, high standards and rewarding excellence, exposure to superstars and learning how to be ‘a good horse from a good stable’. In the following section, each of these influences will be described in more detail.

Inspiration and enthusiasm

At interview, many of those who recalled being influenced by their teachers described individuals who possessed an obvious passion for the subject material. There was a sense that these teachers were genuinely excited by teaching their subjects, in many cases demonstrating key concepts in novel ways or engaging students with tales of new developments or major ideas. One such example comes from the neuroscientist Ray Tallis, who recalled the inspirational impact of his biology teacher, Frank Swallow:

He was a brilliant teacher - so much so that I wanted to please him and show off to him a bit, so I would always buttonhole him at the end of a lesson and he was always very patient... and for 5-10 minutes I would ask about things. And he was very inspiring. This was around the time, in the early '60s, when Crick and Watson got the Nobel Prize for the structure of
DNA and so on, and one really felt that the secret of life was going to be found and the secret of anything important was to be understood in biochemical terms… he was terrific.

**Acknowledgement**

A number of interviewees recalled the positive impact of particular teachers whom they felt had recognised their particular interests or abilities and tried to channel them into extending their knowledge base and confidence. Of these, some recalled teachers who had quietly facilitated a pathway to the next level of knowledge. As Adam Spencer recalled of his second grade teacher, Miss Russell:

...she one day used the phrase ‘you can’t put a square peg in a round hole’ and I very politely put up my hand and actually said, ‘but miss, if the diagonal of the square is less than the diameter of the circle, the square peg will fit quite easily through the round hole, won’t it?’ I was a bit challenging for a second grade teacher to deal with but she was great...she was the one that realised with me that I wasn’t trying to be a dickhead and I wasn’t trying to hassle other kids, I was just frustrated... she would take me aside in the playground at lunchtime and say ‘look, when we come back, we’re going to do some of these multiplication questions in class. I’m going to try and get the class through these 10 questions, I bet you can’t go down to the library and do all fifty of these in the time that we do ten.’ (And I’d say) ‘You watch me, Miss Russell!’ I’d go down and I’d do all fifty. I’d mark them from the back and I’d get up there and they’re only up to about question eight. I would be there going ‘how much smarter am I?’ and I’d be really happy that I’d been set that challenge and been able to meet it. She was great at channelling my real ability and just... (my) passionate desire to do it.

For others, the recognition from teachers was more public, which sometimes brought with it mixed emotions. As Mike Archer recalled:
Mr Problemen, the science teacher in high school... reacted to kids he understood were not just there because they had to be there. He memorised the science book. He knew every word on every page and he knew I almost did, so whenever we'd have science classes and he would ask a question of somebody else...and they didn't answer it, he'd say 'Mr Archer, what does it say on page 237?' and I'd tell him...

For Archer, the teacher's direct recognition of his advanced knowledge was embarrassing but also confidence building; later going on to win the National Science Fair, his teacher would become the trusted mentor to provide support when the opportunity for further learning arose:

When I won the National Science Fair, I had a choice. It was the first time I’d ever left New York State and... the Science Fair organisation in the United States said you could bring one person with you to Albuquerque, New Mexico. And I picked him.

In both of these cases, it was evident that the school teacher had recognised some underlying ability in their student and found positive ways to nurture and extend that interest. A similar effect was observable in people's experiences of university, particularly as they transitioned from undergraduate to graduate studies. For some, this transition marked a time when science first stopped being easy for them, creating a sense of vulnerability and confusion. An example from Lawrence Krauss reveals the importance of an influential instructor at this time:

As an undergraduate you have this illusion of being good... you think you're wonderful. Then you go to graduate school and you actually have to do something, eventually. There isn't a lot of support. You have mentors but you're the lowest on the ladder. You're surrounded by people who are often good, and who also feel very similarly... I had one instructor at college who was a physicist... he just had this great belief in me, at an important time when I felt so low.
A number of participants similarly recalled the transition from undergraduate to graduate school as being very difficult in terms of their sense of self-esteem and capability. In such an environment, feeling that somebody else had faith in their abilities was a crucial element in their decision to continue on to the next level. As Krauss observed of surviving that transition, “I went from MIT to Harvard and the same people who had totally ignored my existence as a graduate student suddenly thought of me as some person who should be talked to.”

Like Krauss, many other interviewees felt that during their time at university, close role models had helped them to gain confidence and autonomy. Another relevant example came from Hugh Montgomery, who recalled:

I had one very, very powerful influence on me. He was my professor. He sort of took me under his wing and nurtured me, a bloke called Eric Neill who was a fabulous polymath. He’d not only been at the top end of the Physiological Society for years and made some of the very big modern-day findings in circulatory physiology but he also was a national fell running champion and had records on golf courses and a couple of professional jazz records... (he) used to sort of reward me when I bunked off my PhD and disappeared off to do something else. I disappeared for a couple of weeks to break the underwater piano playing record, which he thought was fabulous; that I hadn’t turned up to his lectures to do that. He was very much encouraging us being a little atypical. Yeah, so he was tremendous, absolutely tremendous.

**Scaffolded knowledge**

Some participants suggested that teachers had played an important role for them in recognizing their obsession for certain things, such as collecting or cataloguing the natural world. One such interviewee, Mike Archer, described experiencing a powerful ‘hunger gap’ between what he actually knew and what he desperately wanted to know. It was this pursuit of information that led him on a journey,
whilst a teenager, to meet an influential mentor possessing far greater knowledge than himself:

I needed at that point, probably from the time I was fourteen to meet someone who was way ahead of me but who could interact, who I could talk to. I would go to the American Museum with my suitcases full of stuff and I met Norman D Newell...although he was a researcher he obviously spent a lot of time interacting with crazy kids like me. When I went there I didn’t know him and...I ended up with him in a room and he said, what have you got? I said I’ve got two suitcases full of Devonian fossils – I’d identified the age by that time...He got excited. It’s a wonderful rapport because he looked, he said ‘God that looks like Peronopsis but that’s not \textit{interstrictus}, you know!’ Instantly, communication and shared enthusiasm. Every year, I was down there again with the next suitcase of stuff. It went on all through high school and I started to lead expeditions...

From this account one gains an impression of Archer’s knowledge being scaffolded and galvanized by exposure to the advanced understanding of a more learned advisor. Indeed Archer would prove to be just one of a number of eminent scientists to have been mentored by Newell, whose other protégés reportedly included both a range of esteemed palaeontologists (Eldredge, 2005) and the noted biologist, Stephen Jay Gould (Gould, 1989).

Similarly, the astronomer and \textit{Sky at Night} presenter, Chris Lintott, recalled how he came to see himself as an astronomer:

Partly I fell into it, I think. I’m somebody who has always been an amateur astronomer as well as a professional one; so I grew up in my local astronomical society as a member of the British Astronomical Association, and contributing very bad sketches of the planet Jupiter and trying to take images. My school had a huge telescope, half-metre reflector, that they ridiculously gave us the keys to, so trying to take images of active galactic nuclei with a CCD chip that was tiny, and not getting anywhere, but
thinking of myself in that community. So from there you get used to people - there’s a culture of not just professionals coming to these societies and talking, but amateurs presenting their results. So I did a bit of that and came across Patrick (Moore). I was one of the many kids who wrote to him. He came to my school when I was 11 or something like that and I wrote to him afterwards and got a reply and kept up a very eager correspondence. I have a wonderful postcard back that said ‘Dear Chris, Yes. Patrick ... He bothered to reply.

An interesting aspect of these accounts is the context in which the exposure to influential mentors occurred – outside the formal learning environments of school, and as a direct result of the individual’s personal quest for further knowledge. For these young scientists, the recognition and consideration they received from their mentors was particularly empowering; not only had they achieved their own personal goals but they had gained access to a new level of knowledge and a broader network of helpful experts. Such ‘head starts’ seem to have helped place these individuals firmly on their pathways into science, and accelerated them in terms of both their knowledge and their confidence.

**Practical exposure**

For many participants the process of being introduced to ‘real’ science or advanced research was particularly influential. In a number of cases, teachers provided the opportunity for youngsters to participate in scientific research while still of school age, an exposure that positively influenced the individual’s attitude towards science. In one such example, Robert May recalled how a particular chemistry teacher at Sydney High School, Lenny Vassar, had “pushed him” in the direction of chemical engineering:

I wasn’t doing something academic. I was doing a professional qualification. It was the way he taught...he said ‘the people who are taking honours are going to go on in chemistry and you might start learning how to learn for yourselves now’. And he had a library of past essays around
themes in the syllabus that was available and you would chose some of the topics in the syllabus and go through it for yourself, (then he would say) ‘come and talk with me if you want to’. Really quite an extraordinary person. He didn’t like grading exam papers. So he used to hand the papers out to the class to mark each other’s papers...And, so I went on to do chemical engineering.

According to May, Vassar was instrumental in teaching a significant number of esteemed scientists beside himself, including “no fewer than eight fellows of the Royal Society, including one Nobel laureate and one president of the Royal Society.” May’s claim is backed up by a listing of eminent Australians published in the Who’s Who in Australia; science alumni from Sydney High School of similar vintage to May include bionic ear inventor Graeme Clark, the Nobel laureate Sir John Cornforth and the epidemiologist Sir Michael Marmot, amongst many other high achievers.

Central to May’s account is the idea of ‘learning how to learn’, which was echoed in a number of other cases. And one of the key ways in which this learning was achieved appears to have been through exposure to the practices and knowledge of ‘real science’. When contrasted to doing ‘just another practice exercise’ a number of participants suggested that they had gained a greater sense of excitement and personal autonomy by learning to do things themselves that ‘real scientists’ did.

Some participants described in detail how being exposed to the skills of others had impacted positively on their own research ability, by teaching them crucial practical skills. Gustav Nossal, for example, described his experience of learning experimental skills from both Macfarlane Burnet and Joshua Lederberg:

Burnet taught me there is no such thing as a failed experiment. He truly believed that. He said every experiment that I did, if the result was different from what I expected, nature is trying to tell me something. There are failed interpretations but there is no failed experiment. Unless

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you dropped a drop of acid in the tissue culture or something like that, I thought that was very interesting. He somewhat mischievously said ‘I never repeat an experiment’, now of course that wasn’t true, but what he did was, when the experiment gave a certain result the next day, when he did it again he introduced some little new wrinkle, some extra control or some extra probe that might take the discovery a little bit further. Now Lederberg, on the other hand, actually physically taught this and other things with his own hands. He happened to be an expert in micromanipulation because some of his experiment required a single bacteria to be put into a tiny little droplet under a microscope and then to multiply up and then the progeny could be tested for this and that quality. And that allowed me to begin to study single antibody forming cells through a variant of the techniques, which he physically taught me, and that kept me going for quite a few years with a little technique of my own that no one else could do.

Talent

Many of the ‘influential others’ recalled at interview were characterized as being talented scientists who were able to pass on critical skills to their protégés. Gustav Nossal further described his experiences of being inspired by two giants of the medical research world:

Mac Burnet (was a) very deep thinking person, the word lateral thinking was invented for him. He was the person to put disconnected facts together; one and one didn’t make two, it made three. And that was his great gift. Probably his biggest contributions were of a theoretical nature, which is unusual in biology... (but) Burnet would always have to ponder a problem, he’d have to take a pencil and draw a little diagram and look at the data this way and that and take it home, then come back the next morning with the solution. Whereas Lederberg was so bright that while you were articulating a thought he’d interrupt you in the middle of the sentence and say, ‘Yes, Yes I know all that go on.’ Lightning fast mind, at
his best in the thrust and parry of a discussion with a gifted colleague or student and just a very different style of brain. I just feel I learnt so much from seeing at first hand and quite closely these two different types of scientists at work and also working with each other.

Nossal’s account exemplifies a key theme emerging from the research – that of talent begetting talent, or in other words, of scientific talent being nurtured by a preceding generation of experts.

Similarly, the microbiologist Nancy Millis recalled two very influential figures:

I took a year on a scholarship in the States and I went to Wisconsin University and there was there a chap called Marvin J Johnson. He was an absolutely remarkable person. He was able to turn his hand to almost any branch of the physical or biological sciences, just a remarkable person...he was a rigorous scientist and a very good one at that. He was a very influential figure in my life. (And) Sid Rubbo was an interesting man in a different way... he was a good scientist but not a great one, but he had a wonderful capacity to produce an ambience in the department where science was regarded as a very important activity and one in which collaboration between people was significant. He had a great regard that people talk well.

Millis’ account is interesting in that it highlights several key values associated with science: disciplinary expertise, rigour, research success and communication.

High standards and rewarding excellence

A number of interviewees made mention of the high professional and academic standards demonstrated by their influencers, and the benefits that arose from being able to meet or exceed that standard. As Gustav Nossal recalled of his hero, Peter Medowar:
This chap was brilliant, he was extremely handsome and personable, he was about six foot three tall, very charming, he was half Lebanese, but made it to the top of the British Establishment and you can imagine what an achievement that was in the 1950s. And he certainly didn’t suffer fools gladly but, if you were someone that he approved of intellectually, could be extremely charming and articulate in discussions with you...

Bryan Gaensler similarly recalled the experience of studying under his high school chemistry teacher, who had a PhD in chemistry and continued on with research collaboration and publishing whilst also teaching:

...he was really not very patient with students who weren’t up to his standards, (but) if you were prepared to work hard and match him he would take you way beyond in the syllabus...

Gained from these accounts is an impression of individuals aspiring to reach a high standard of performance, which has been modeled for them by a more experienced other. In meeting the standards signalled by their instructors, a number of rewards become apparent. These include gaining the obvious pleasure and approval of the instructor, as in Nossal’s case signalled through the charm and extended conversation of Medowar, and admittance to a higher level of knowledge, as in Gaensler’s case. In both examples there is a sense of the pleasure and social reinforcement that was experienced by the individual, in knowing that they were of the right calibre: part of a small elite who could meet the exacting standards laid out before them.

**Exposure to superstars**

The experience of meeting extremely famous or widely admired others was recalled by a number of people participating in the study. Some individuals recalled specific events in which they had encountered ‘giants’ of their fields, in some cases previously distant role models whose appearance had a profound impact on them. In one example, the neuroscientist Larry Farwell recalled the
impact of experience of spending time, as a young teenager, with Niels Bohr and Werner Heisenberg:

Niels Bohr was very inspiring to me; he's one of the great physicists of all time. When I was 12 years old my father took a sabbatical and went to Europe, to Copenhagen to study at the Niels Bohr Institute. So I played with Niels Bohr's grandchildren but I got to know him... I found him a very inspiring person because first of all he was a very sweet man. He was just very, very gentle and sort of grandfatherly and he was brilliant. He was also sort of a renaissance man kind of a person, he was an athlete, he was very socially active and happy and sort of socially interesting person. So he was an inspiration to me.

Niels Bohr and Werner Heisenberg went through some really intense personal emotional changes when they started to get down to the level of physics where the observer is a part of the process, where human consciousness enters the equations, because everything that had been the basis of science and of their science education for the last 400 years was being trumped. It's like the rug was being pulled out from under them... My father was very young and he was a generation younger. But he was a part of that whole phenomenon in the early days of physics when quantum mechanics was being discovered, when relativity was being discovered. So that process of sort of taking the world as we know it for granted and then finding out that actually that's not what the world is like at all was something that was deeply inspirational to me because it made me realise that that's what scientific revolutions are about, that's what the true process of discovery is about.

Farwell's account is interesting for many reasons, not least of all for the broader context he places around his experience of interacting with Niels Bohr and his awareness of the significance of his life and work. Recalling the relationship between his father and the older man as one of working at a new frontier in physics, Farwell also expresses a feeling for history in the making: however peripherally, he was a part of and fundamentally shaped by it.
While Farwell’s account suggests the impact that exposure to science superstars over a sustained period may have, Gustav Nossal recalled a very specific encounter that for him triggered a profound insight:

I remember the first occasion that I sighted the fabled Sir Macfarlane Burnet. It was in 1950... he gave a lecture to some medical students, just an adjunct lecture at 4 o’clock in the afternoon, a special lecture in a big barn that we had just outside the medical school... And he was talking about polio. He said ‘I have to tell you, lads and lasses, that a man called John Anders at Harvard has just succeeded in growing all three strains of the polio virus in tissue culture and a very young man called Salk is attempting to make this into a practical vaccine.’ Now, we had grown up in an atmosphere where these bad polio epidemics would come every three or four years, and even in an off year there was still polio... And kids would get paralysed and a few kids would die. Our mothers would not let us go to the cinema or to the swimming pool because you would not go into crowds where you could catch polio. And here was I sitting there listening to this inchoate discovery and here was someone saying to us ‘a polio vaccine is coming and when it’s widely used polio will be gone’. And you know it’s gut wrenching. It had a tremendous affect on me and I’ve never forgotten it. And that is the endless quest. These very big tools, these very big new weapons can actually wipe a scourge from the world.

Nossal’s recollection paints a picture of a young man who was powerfully captivated by the idea of medical science as a life-saving and game-changing enterprise. In it, the message presented by Burnet is both crystal clear and close to home: Nossal learns that new discoveries are occurring that will change the world as he knows it, promising to make his own experiences of polio – characterized by fear and vulnerability – a thing of the past. There is a sense that the story Burnet told resonated deeply with Nossal, helping to fuel his desire to take part in that ‘endless quest’.
Others also recalled the power of big ideas and the influence of those associated with achieving them. In contrast to Nossal, whose first, striking encounter with his hero occurred very early on his career, others recalled interacting with major figures within their fields at different stages throughout their careers, learning as they went. One particularly rich example came from the oncologist, Ken Calman who said:

The key to all of it, really, is that there were a number of people that I worked with who were truly inspirational...the first I guess was a professor of dermatology. May not seem too exciting, but he had a wonderful way of making you work hard and showing you that the little things that you were doing actually were quite useful. I then worked with a plastic surgeon who was just outstanding. Not only technically outstanding, but he had been at the heart of a number of major changes in plastic surgery. So I had two or three hours staying in an operating theatre with this man who’d had huge experience of the world and surgery, and we’d just talk. The professor of surgery that I worked with was just amazing. Again, not just technically, but in his range of things that he was interested in. When I went to London for a year, I worked with a scientist, an immunologist in London who completely changed the way I thought about certain things, because he was an amazing individual. All of these people had a huge impact on me... First of all, they all worked enormously hard. They just worked all the time and they were available all the time if you wanted to talk to them. Secondly, they had a huge interest in what we did. They had enormous breadth of interest, so although they may be specialists in X - or they would have to be - they actually knew about a lot of things and therefore they could talk broadly about the world and what was happening in medicine generally. That was just great, and one in particular was extremely challenging. He would attack you at times in terms of what you were doing and you really had to be up to the mark...or you lost. So I mean I think they were great, I’ve been hugely fortunate.
Calman’s account suggests a process of continual learning, under the tutelage of experts in the field who set high standards, demonstrated mastery over their domains and shared new knowledge with him that further expanded his professional horizons.

 Whilst the above cases are examples of ‘near’ role models, there were also many examples of ‘distant’ role models presented at interview. One such example came from Anne Glover, who felt that it was only after years of narrow focus that she was able to think about science in its wider contexts and take inspiration from areas outside her own field. Upon reflection, she recalled it was the fundamental importance of her hero’s work that really inspired her:

  Peter Higgs has worked most of his life at Edinburgh University and just the fact that in the early sixties, he came up with this wonderful concept of the Higgs boson and how that might unify our understanding of matter. And his clear thinking on that one thing has stimulated hundreds, probably thousands of other scientists, to be able to address that question and work towards it... people always think that important scientists or important anybody in the world, they have to be ruthless and aggressive and so on. He is just one of the nicest people that you would ever hope to meet. He is gentle and unassuming and just intensely clever... Finding out a little bit more about him made me very appreciative of what he has done and what he has contributed in general for science...

 Glover’s experience shows that one’s heroes can come from disciplines other than one’s own. It also suggests that the hero’s role is multi-faceted, evoking a number of emotions including gratitude, wonder and inspiration. Like Nossal and Farwell, she perceives her hero as being at the forefront of his field, characterized by bringing new information or techniques to address fundamental issues. However, she does not contemplate following Higgs’ footsteps herself. His power lies in the way that he models the most positive and important aspects of science – its huge reach, the importance and excitement of its potential applications, and the idea that ‘nice guys’ can still come first in science.
This idea was reinforced by observations made by the biologist, John Coggins, who referred to the importance of his role model, the biochemist Fred Sanger:

He won two Nobel Prizes. I didn’t work directly for him but I worked for a number of people who did work directly for him and he had a tremendous eye for detail and experiments. He always had a very small research group. He believed that what he should focus on was doing what he called small experiments really well and then adding them together to get a big picture. He did things that were relatively simple. He designed really relatively simple equipment. I mean the equipment we now use to sequencing DNA he kind of thought out the strategy to do that in the 1970s and the early 1980s and it was so simple and it worked and it went on and on working... here's somebody who stays at the bench, does their experiments, is down to earth, absolutely not arrogant but is totally trustworthy. He did his experiments, he did them very carefully. When there was an odd result he would be talking about it and trying to learn from the odd result, you know, what are we doing wrong because we've got this odd result? What new hypothesis do we need? He just was absolutely simple and logical in the way that he did everything. He was also very modest. He didn't really like giving great big lectures. He was much happier to lecture to 20 or 30 people. He didn't like these sort of grand conferences where he'd have an audience of 1000; he didn't enjoy that...he was a very humble guy.

Coggins’ description of Sanger is reminiscent of the description made by Collin Pinch of the ‘quietly confident’ heroic archetype. Just as Pinch described Ray Davies, Sanger is recalled by Coggins as having humility. This characteristic was also highlighted by the biologist, Nancy Rothwell when describing her distant but 'total hero', Peter Medawar:

...his books (were) so wonderful. Advice to a Young Scientist is one of the most important books I ever read, which was when I was doing my PhD. It’s just a wonderful book. It’s so humble. It just made me think of science
as a whole culture, rather than just a doing thing, that there was so much to it. Because his books have advice on managing your supervisor and on how you deal with your family and all sorts - on the ethics. Very high moral ground book, in a way, as I gather he was.

In addition to qualities of modesty or humility, other inspiring characteristics of role models cited at interview included those having a ‘positive take’ or good perspective on their work, accepting that progress occurred as stepping stones rather than great leaps, and those who worked and communicated well with others.

**A good horse from a good stable**

One significant theme to emerge from the interviews was the role of luck, or being in the right place at the right time, which many considered to be a factor in the relative success of their science careers. A number of participants felt strongly that they had experienced great fortune in attending particularly good schools, studying under great teachers, or being trained at universities where scientific talent was greatly concentrated. As Gerry Wasserburg described it:

> When I was at the University of Chicago, I was surrounded by the smartest people in the world...The large number of prize winners and Nobel laureates that came out of there is fantastic. That was partly because it was a good stable. People looked at important problems and asked important questions and even if you didn't understand it, if somebody really smart asked you something and you thought about it, you were suddenly doing something important whether you liked it or not.

Like many others, Wasserburg’s exposure to important problems came as a direct result of completing graduate studies amongst some of the best and brightest in his field. Similarly, astrophysicist Paul Davies commented on the role of luck and networks:
If there's a field of research that rapidly opens up then being in the right place at the right time helps, and if your thinking is along the right lines, if you're very good you can actually develop the field yourself. You set the agenda because you've come up with some deep insight and the whole field of endeavour opens up. More often than not, that is not what happens. Certain things suddenly become either fashionable or there are some new results in rapid succession and the subject develops. But I still do think that there is this very large element of luck... everyone needs a job and you know, if you're in the wrong university or you have a difficult departmental chairman or something, you may not make much progress anyway. I was lucky that I - well I say luck, it's an interesting story. When I was doing my PhD I was given a problem to work on that Fred Hoyle had been working on and thought 'well, the obvious thing would be to make him external examiner for the PhD thesis because you know, unless I've screwed up on this, he surely is going to approve the thesis. But also because maybe he'll give me a job afterwards' and that's exactly what happened. It worked like a dream. So I went to Cambridge because Fred knew who I was and had read my thesis and I went there and got to know people like Martin Rees and Stephen Hawking. I was casting around for new direction and sort of stumbled into this quantum and gravitation together, which, a year or two afterwards became all the rage after Hawking's black hole result. By then I was at King’s College in London where I happened to be with exactly - well we always thought we were the best group in the country...It had a strong tradition. I got that job and it was just luck.

From Davies’ account an impression is gained of an ambitious young man who recognised that meeting the 'right' people and being 'in the right place, at the right time' would be crucial to his future success. Another key perception conveyed by such accounts was that some institutions are far better than others, by virtue of the people who lead the science there. Robert May described in detail what it was like, as an undergraduate, to realize the importance and excitement of the scientific work going on around him:
I’d never given thought to the question of how the canon... was created. It was only at university, and I was lucky that Harry Messel had arrived just a year before I arrived as an undergraduate. And there was an extraordinary collection of people in the physics department... Messel had assembled them. One was Australian, a chap called Stuart Bartlett who had just come back from having done a thesis with my intellectual grandfathers... great figures of the golden age of physics in the ‘30s. One of them is Wolfgang Pauli... Another is a chap called Rudolph Pyles... the co-author of the method that set off the Manhattan Project (who) had around him a group of people after the war in Birmingham that was just the centre of theoretical physics. It included people like Mark Oliphant, Freeman Dyson, Brian Flowers... Sam Edwards, arguably the best theoretical physicist of his generation. An extraordinary group of people, and Stuart Bartlett was one of them. Another, my thesis supervisor, (was) a chap called Robbie Shathroth, who was Pauli’s assistant. And the third one was a chap called John Blatt who had written what was then the standard textbook on nuclear physics, with Victor Weisskopf, who was the first director of CERN... I was going to go to Geneva. The hot topic of that time, which was what my thesis was on, was superconductivity...

Such accounts summarise a number of critical aspects that participants associated with coming from a ‘good stable’. First, there is the concept of the institution itself working to attract star performers into the fold. Second, there is the concept of those star performers attracting other talented researchers, effectively creating clusters of excellence within the institution. Third, there is the concept of lineage within science, where an academic pedigree begins with individual talent, initially developed under a particular mentor and then extended through development opportunities overseen by the mentor’s key contacts – in essence linking a protégée into the extended academic network and helping to strengthen the clusters of excellence in which they have involvement. Fourth, there is a sense that protégées gains great benefits from association with the greats in their field. As they become drawn deeper into the training grounds of the research environment, they are able to access the superior skills and
knowledge base that it contains and also become exposed to the big ideas that are circulating within their fields.

Finally, there is the concept of the ‘golden age’: a time within the research field when groundbreaking scientific discoveries are occurring, creating a frisson of excitement and opportunity that attracts bright and ambitious researchers to the fold. A degree of ebb and flow is discernable within that concept; as May recalled, Pyles’ lab in post-war Birmingham had become the key centre for the theoretical physics of its day. Nevertheless, by the time that he himself had joined the fray, key individuals had shifted their focus elsewhere, re-clustering to form a new centre of excellence at Sydney University.

A range of motivations could be postulated for the movement of individuals, including that the most exciting opportunities have shifted to other loci under other star performers, or that individuals have leveraged their reputations to negotiate more influential positions elsewhere, effectively striking off on their own to start a new cluster. Personal factors too may come into play; it is reported, for example, that Blatt did not suffer fools gladly and left MIT for Sydney after becoming unhappy with the political atmosphere under the McCarthy administration. Having established a successful cluster at Sydney University, he was subsequently recruited to become the foundation Professor for Applied Physics at the University of New South Wales, by a vice-chancellor who admired his “aggressive personality”. (Franklin, 2001)

4.8 Discussion

Chapter summary

This chapter explored the key influences on pathways into science as reported by participants at interview. As the results show, these were enormously varied with myriad personal experiences described, including those from early childhood, those relating to family upbringing and value systems, experiences of opportunities to acquire and practice scientific skills (both in and outside of
formal learning environments), the presence of intrinsic and external motivators including family expectations and peer competition, and the importance of ‘inspirational others’ that were encountered and located by individuals in a range of different contexts.

From the accounts given, it is clear that there are many different influences at play, and that these combine in unique ways to create experiences specific to the particular circumstances of the individual. As a result, no ‘average’ experience can be derived from, nor could be considered truly representative of, the data; the accounts given were so complex and in many ways so contradictory that such an attempt would be impossible.

In attempting to summarise the breadth of experiences reported, one can only say that, for some people, an interest in science appears almost fundamental to their lived experience of the world; for many it was recalled as being a defining part of their life for ‘as long as they could remember’. Others, however, reported feeling that their interest emerged slowly over a long period, while for others still it appeared rapidly and dramatically within a relatively short timeframe, often in response to specific experiences or opportunities. Some people were self-described ‘science kids’, whose favourite childhood pastimes were related to science or to the natural world. For others, a love of science was experienced quite late, as a result of influences felt at school or university, including from great teachers or knowledgeable mentors. Outside of formal learning environments, inspiration was also found in myriad places: within the pages of books of almost any genre, inside the layered experiences of video games or television shows, or within the fascinating construct of museum exhibits. For some, clubs and societies or science fairs provided fertile ground for doing self-directed ‘real science’.

Some people were evidently born into families steeped in scientific culture, exposed to the experiences and attitudes of previous generations, or excited by relatives’ tales of achievement and impact. Some were brought up in environments where families were generally rather than specifically supportive,
or where doing experiments or tinkering with technology was the norm. Yet many others were born into families with no obvious connections to science at all: they recalled no early interest or experience in science, but pursued other ideas and hobbies; many recalled formative years marked by verbal sparring, theatre, sports or music, with science only emerging as an interest in later years.

Nevertheless, despite their huge variety of experiences, all of the individuals in this study did ultimately pursue careers in science of one kind or another. And perhaps it is this very diversity that provides an answer to the question of why people pursue a pathway into science.

Discussion

Participants were asked about which influences they regarded as important, which they subsequently described in varying degrees of detail. In many cases these descriptions were profoundly revealing of the emotional, social, physical and academic journeys experienced by the individual as they progressed through their careers. In the act of recalling important experiences and decision points, tales of self-identity began to emerge in the form of anecdotes. In many cases these narrative elements connected particularly memorable experiences together; but there was also a sense that individuals had consolidated and in some cases rehearsed these tales, in order to make sense of their own lives. Some were particularly well-rehearsed in their storytelling, most notably those who had a significant public profile or were experienced public speakers or presenters.

In many cases, when pressed for further detail about the experiences they had raised as being important, participants remembered either more complex information about what was a particularly powerful experience or provided further examples of additional experiences around the theme. In the latter cases there was a sense of cumulative impact: of recurring and often interconnected events contributing or compounding over time.
From every individual the impression was gained of a complex life lived, in which many different choices, opportunities, preferences and possibilities presented themselves and in which many important insights and decisions occurred. It was clear that individuals’ decisions were made on the basis of the particular desires, value systems, motivations and pressures occurring at the time, and for some, there was a sense that things could have been different if it had not been for particular events or influences they experienced at key moments in time.

The body of evidence presented here is truncated; it is a subjective snapshot gathered from individuals at one particular point in their lives, each progressing through widely varying careers. Nevertheless the accounts give us a glimpse of the complex and interconnected web of experiences that have affected and in turn effect the unique science pathways taken by each individual. And it is from this notion of highly specific individuality that some overarching themes emerge.

**Powerful imaginings: the importance of visions for the future.**

Ultimately, almost all of the participants completed studies in science and then pursued either some form of science career, or one in which science has played a significant role in terms of their personal or professional identity. Beyond the universal experiences of progressing from childhood, through school, and then out into the world of employment usually by way of university, the means by which they had gained their sense of science identity varied enormously. The myriad of individual life experiences, situated in a wide range of family and community contexts, is what has ultimately informed, shaped and supported the individual.

Some researchers have recognised the role that individual life experiences play in yielding knowledge that is useful, powerful and transferable. For example, Basu and Barton (2010) found that “when students...could choose and engage in activities connected with their visions of the future, how they valued relationships, and their definitions of science, they developed a strong, long-term commitment to pursuing science” (p. 487). This finding rings true within the
present study, in which many individuals referenced strong family, education and science community experiences that helped to create a sense of identity, interest and achievement.

Clearly emerging is the idea of individuals driving their own paths into science from a basis of interest, inspiration, opportunism and experience, often from a young age and frequently supported or informed by modelling from older, more experienced people; from the widely varied accounts of the interview subjects is a crystallising sense of the desire they experienced for more science; and it is this desire for more that appears to create deeper engagement and prioritise higher achievement with the subject material. This is not ‘subject material’ in the traditional, educational sense. Rather, it is the subject material of the mind’s eye: material that fans the flames of curiosity and stimulates a desire to know more. Material on which the individual’s imagination can feed, helping to create a vision for their future in which science plays a key part.

Researchers such as Lloyd and Wallace (2004) have called for teaching about science futures to be incorporated into the curriculum, and the further evidence from this study supports that call. For some participants, their sense of identity as a scientist appeared to build up slowly over time, as multiple experiences and expectations scaffolded and reinforced one another. They often had a foundation in childhood, beginning with characteristics such as curiosity, play, collection and observation, which then evolved into more complex and controlled processes of experimentation, discovery and invention. These connected elements helped to develop and refine the individual’s interest and also helped to create new opportunities for extending it.

For some people, this vision of the future offered a reprieve from periods in life when the social world was difficult to understand. Many described experiences in adolescence that played a crucial role, often strengthened and extended by the support of family members or influential adults. For instance, in the case of David Suzuki, living a pariah’s existence on the fringes of Canadian society, isolated from his peers by virtue of his Japanese heritage and driven to achieve by an
awareness installed by his father, of having to prove himself better than everybody else, the vision of a better, future David was clearly worth fighting for.

For Mike Archer, playing alone in the wild swamplands of his frustrated early adolescence enabled him to collect specimens and ambition in perhaps equal measure: ultimately, he boarded a train to New York where Newell would be waiting to change or, perhaps more accurately, to reinforce his life. Similarly, the young Fraser Mustard would confront a difficult entry exam question by drawing on his lived experiences of observing beavers in the wild; whilst his knowledge may no doubt have been supplemented with information from other sources, his sense of empowerment at being able to achieve on the basis of his own knowledge is tangible.

For Barry Marshall, voracious reading about adventurous scientists and tales of surgical derring-do appear to have conjured visions of an exciting and important possible future for himself: one in which he would be at the forefront doing ‘surgical stuff’. And again and again throughout the interviews, participant accounts revealed this sense of an attraction to future work that was real, life-saving, world changing, ground-breaking or otherwise exciting. The science they saw for their future selves was not mundane, but heroic.

In the 1995 film Apollo 13, the hero Eugene Kranz states that “Failure is not an option”. Whilst perhaps aptly summarizing the mood of NASA crew towards the mission, in reality a longer account of the attitude from flight engineers reveals that something more complex and more nuanced was occurring. As one flight engineer, Jerry Bostick, later recalled: “...when bad things happened, we just calmly laid out all the options and failure was not one of them. We never panicked, and we never gave up on finding a solution” (Woodfill, n.d.). The values of persistence and problem solving in a collaborative environment, focused on the common good, are clearly evident.

Similarly, many participant accounts suggested views of science as being self-oriented and useful, and suggestive of a boon that has both creative and practical
value. Strongly detectable were ideas of ambitious utility; of success through ‘stick-to-itiveness’ and contributions to society and of making one’s mark in positive ways. For example, according to the young inventor, Emily Cummins, who built experimental machines at her grandfather’s workbench, she was both challenged and encouraged by his interest; also amply resourced to try, and on failing, to respond with new approaches and try again. Similarly, as Nossal recalled learning from Macfarlane Burnet, there was no such thing as ‘unsuccessful experiment’. What seems clear from such accounts is that an ability to persevere can be learned from those who model success as a complex, iterative process in which mistakes naturally occur and are overcome – a process in which success remains possible and over which the individual has ultimate control.

Such iterative progression through experimental design and redesign is a cornerstone of the scientific method. When taught by a trusted mentor or loved relative is seems to be a potent signifier of future possibility. Failure may be experienced differently outside the classroom or within the school environment but perhaps it may be measured on similar terms: the disappointment of not meeting expectations; the desire to outperform an admired other; the impedance to self-actualisation caused by hitting invisible barriers such as not yet having enough knowledge. The crucial point is that the individual senses that achievement is still coming. Possibility remains alive and tangible in these contexts, because it is spoken about or acknowledged – failure does not lead to exclusion but to self-instruction and in the context of play or exploration, it is a means to improve one’s performance next time.

In the accounts of experimental play and self-guided study recalled at interview, curiosity is constantly rewarded by new knowledge and achievement. Self-loathing has no real role, but increasing self-awareness does. Accounts by participants such as Lintott and Steiner confirm that amateur communities of practice can play an important role by connecting individuals to more experienced others who can teach or model scientific behaviours, including data collection and analysis, observation, and the development of evidence-based
arguments. Such a finding supports those of researchers such as Vetter (2011) who have described how lay people participate in scientific observation.

What is fascinating is the way in which this interest appears to be scaffolded and reinforced by experiences throughout their childhood, including in adolescence. However it is difficult to know if this interest is a deliberate construction on the part of an individual seeking to find their place in the world, where expeditions to the countryside (for example) become imbued with scientific meaning over time, in light of all that follows – or whether the experiences themselves create the interest that then leads to something more.

Regardless, the suggestion of scientific identity forming over time, in a personal and social world informed by experiences of many types, is reminiscent of the ‘third space’ thought to exist between the cultural worlds of school and the community – a space that brings together privileged content and discourse from other content areas (Moje et al., 2004). Science heroes can be seen to play a key role in the experiential quality of that space, as it pertains to attitudes, motivations, skills and ideas about the future.

From the evidence given at interview, it’s clear that people can have different heroes in different areas or stages of their life. These heroes may be near, as in the case of parents and teachers, or distant, as in the case of historical figures or admired superstars. They may be derived from many sources, including within families or acquaintanceships, from educational or professional relationships and from sources of imagination and self-actualisation, such as literature and television. Heroes can play different roles within the lives of individuals. For example, some may act as external motivators, modelling professional scientific behaviours, values and standards, whilst others may help develop stronger intrinsic motivation, by facilitating a sense of curiosity, fun or adventure and enabling opportunities for self-guided experimentation and learning in areas of interest. Working together in combination with the individual’s underlying interests and sense of self, over time these important relationships may help to signal clear directions in which the individual can successfully proceed.
Underpinning these relationships are powerful ideas of communication: the spoken and unspoken words that help an individual define who they are, how they feel, and what they want to be. And it is to the question of their communication that this thesis now turns.
Chapter 5: Success and celebrity in science

5.1 Chapter overview

This chapter presents the results as they relate to the second research question: What are the communication characteristics of science heroes, and what can these characteristics tell us about the archetypes of science? It begins with a discussion about concepts of success in science, and explores the impacts and consequences for those who are singled out as science heroes. Consideration is given to the nature of the relationship between the heroes and their audiences, and how this relationship affects processes of science communication and public engagement with science.

The focus of this chapter is on factors contributing to successful career pathways in science, experiences of interactions with audiences and the consequences of those interactions, attitudes towards engaging with audiences and the representations of science emerging from these approaches.

One consequence of pursuing these lines of questioning is that individuals often reflected in depth on their communication experiences, in many cases revealing experiences that had particular personal meaning. In some cases strong psychological or emotional consequences were reported, which were not always positive. Again observing the ‘do no harm’ principle, where such accounts were provided ‘off the record’ or were judged as having the potential to undermine the public or professional standing of the individual concerned, the relevant extracts have been anonymised.

5.2 Characteristics of success

At interview, participants were asked a number of questions designed to probe for their views and experiences of progressing successfully through their careers. When individuals were asked to reflect on what they felt had made them successful, a number of behavioural characteristics emerged as key themes,
including personal qualities, luck and opportunity, the communication of results, lineage, exposure to greats, communities of practice and competitiveness.

**Personal qualities**

Participants often cited personal qualities as being important to their success. Many participants spoke of having a strong desire to ‘keep on finding out’, with a sense of competitiveness providing them with the impetus to keep going. For example, as the Nobel Laureate, Frank Wilkzec put it:

> I’m always retooling, I love to learn things. That’s been important for me. And of course, curiosity. That’s a kind of competitiveness too; you want to see if you can do things better than people who did it before. And also patience. It’s not something that I consciously cultivated; it’s more that if I start to get engaged in a problem I just don’t let go. So it’s not patience in the usual sense, it’s obsession really.

Others also spoke about having a strong desire to constantly improve, with a clear focus on getting better outcomes. For many people, this was expressed as a desire to improve outcomes for others. For example, as the oncologist, Ken Calman said:

> The biggest motivation particularly in medicine is just watching your patients. You think ‘gosh if I could just do a bit better wouldn’t it be great’. I think that’s the bit that says that’s why we need to do a bit more research, that’s why we need to get better at talking to people, that’s why we need to change their social circumstances, or whatever it happens to be, because of them. It’s not about me being a better scientist, it’s about trying to be a better scientist because there are people to help.

Similarly, social entrepreneur Kristine Pearson recalled her passion for continuing to work with the wind-up radio, as a transformative technology:
I became accidentally involved in the humanitarian sector. Really all it took was just one time to see what a difference it made to people who could not afford batteries, especially women. That was really the hook for me... a lot of the programs that are meant for women and families are not actually heard, these people don't have a way to hear them... if they can't afford food, they're probably not buying batteries to power the radio...and of the technologies that we have, radio does enable immediate change. Because information is power. You know, you can't progress if you have no information.

Such accounts give the impression of individuals feeling highly motivated to make a real difference in other people’s lives, to the extent that they could never stop trying to do so; indeed a sense of individuals working to a cause or purpose came through strongly in many of the accounts. For some, their personal drive appeared closely linked to the pursuit of goals that they continually set for themselves. For example, as oceanographer Sylvia O Earle explained:

A lot of people get discouraged but I was compelled not to take no for an answer... For me persistence isn’t an option, I’m just driven. It is not a matter of choice, it’s what I have to do, so you overcome the obstacles. If there is not a suitable way to get where you want to go, you go around or over or under, but you find a way. I have had to give up on some things but there are some things I continue to pursue, even though I haven’t achieved them yet.

The physicist Lawrence Krauss, who also described having a sense of being able to persist in the face of adversity, echoed Earle's description of feeling driven and highlighted the necessity of personal reinforcement in order to persist:

You have to be driven by something internal and be willing to be focused on your own interests, to the exclusion of a lot else. You have to be satisfied with that because most of the time in science, things don’t work. That’s the other thing people don’t realize. Most ideas are wrong or whatever, so there has to be something internal that continues to drive
you. It can be, rarely, external stimulus or external reinforcement. You have to somehow reinforce yourself. I think that’s true to a great extent, because a lot of the time it’s difficult and frustrating.

Such accounts are once again reminiscent of the concept of ‘stick-to-itness’, and often recognised as one of the key ingredients of business success. Indeed, whilst not specifically tested for, many of the accounts given at interview strongly suggested the presence of the ‘big five’ personality traits that researchers such as Judge, Higgins, Thorensen, and Barrick (1999) have linked to long-term career success. Across professional disciplines, typical traits of the most successful individuals include high levels of conscientiousness, of which persistence is recognised as a sub-set and openness to experience, of which intellectual curiosity and creativity are features.

**Luck and opportunity**

The majority of participants also felt that luck had impacted on their careers, in a multitude of important ways. These included feeling that they had ‘met the right people’, had entered a field as it was ‘starting to take off’ or had just happened to be ‘in the right place at the right time’. One particular example came from Wally Broecker, who according to his peers is “a genius and a pioneer, the Grandfather of Climate Science” (Colombia, 2015). At interview, Broecker said:

I’m lucky. I entered the field right at the right time. I came here in ’52, so it was enough after the war that things were really getting going. The field of isotope earth science was still in its infancy. We had meetings in geochemistry that included Europe and North America, there'd be 50 people, maybe 30 of them were graduate students and that was it. Now there must 50,000. It's huge. We have the American Geophysical Union, 13,000 people. That's a small fraction of all our number. So I got in on the ground floor.
Similarly the Nobel laureate, Peter Doherty, felt that he had entered medicine at a time when opportunities for young researchers were plentiful and more easily achieved:

Biological science is now much bigger than it was when I was getting into it. It was a particular point of time in science – the experiments we did were very cheap and simple because the technology didn't let you take them any further. We just published two one-sided letters in Nature and a two-sided hypothesis article in the Lancet, and that was the basis of our Nobel Prize. Now, it takes forever to get anything done... There will still be discoveries that are a paradigm shift. But if you have many researchers involved in a project, the most senior researchers are probably more likely to get it, and the junior researchers – for example a postdoc who did the research – will miss out.

Others felt that their connections and interests outside science had played an important part in their overall success, as had their willingness to talk to the media. Once particularly pertinent example came from the biomedical scientist and broadcaster, Robert Winston, who recalled the role that luck had played in his attempt to re-enter medicine after several years out directing theatre shows:

I applied around for a number of jobs in the field I wanted to do... It took me a while to get back into a really good academic institution. I was very lucky. I eventually got a place at probably what was then the best academic place in Britain in my field, which was by pure luck and by the kindness of the professor. I didn't really have any credentials. I got a research grant from the Medical Research Council. That research turned out to be - I mean it was completely harebrained. I had no experience. I hadn't published anything, had no track record with the institution, hadn't done that sort of work before. There was absolutely no reason why the Medical Research Council should have funded it, but they did. I was terribly lucky. I have been, again and again, constantly - there's been much more luck than anything else in my existence. I don’t think I’m that
talented really. I was lucky enough to get this grant and that lead to about 30 or 40 publications over a period of time. One of them, which was quite revolutionary, was noticed by a television producer... and my research was really starting to forge ahead then. It was becoming internationally recognised - and he said I’m making a program for the BBC... and I’ve been reading those papers that you’ve been writing.

Winston’s story suggests that he attracted crucial funding and a broadcasting role with relative ease, and that this success was best attributed to luck rather than talent on his part. Whilst it is impossible to determine whether this was indeed the case at the time, it seems likely that other factors were also at work. For example, in 2015 the UK’s Medical Research Council reported that 85% of grant applications ‘judged as internationally competitive’ were funded in 2014/15. Presuming that similar principles for determining success applied at the time Winston’s grant was funded, it’s likely that the quality of his application also played an important role in that decision.

Indeed, individuals’ communication skills appeared to play a crucial role in the success that interviewees experienced. A fascinating counterpart to Winston’s ‘good luck’ story was observed during the period of data collection for this study, when in October 2008 the Nobel Prize for Chemistry was awarded to Martin Chalfie, Osamu Shimomura and Roger Y. Tien, for “the discovery and development of the green fluorescent protein, GFP” (Nobelprize.org, 2008). Journalists noted that a fourth man was invited to join their table at the Nobel Prize dinner and soon established that this man was Douglas Prasher, who as a young molecular biologist had first cloned the gene for GFP and recognised its potential applications. Despite having had his research published on the front cover of Science, over time Prasher became disillusioned by the world of science. Frustrated in his research positions, where he experienced a lack of funding and mentorship, and struggling to stay optimistic about his work, Prasher quit first his field, and then science itself. As he did so, he passed his research on to Chalfie and Tsien – two more well-established scientists who had grasped the significance of his work. Years later, Prasher would recall:
The area of bioluminescence was esoteric work; nobody was interested, and funding was very difficult... They were both at hard-money institutions, and I was struggling to get funding. I didn't have graduate students, didn't have postdocs. (Bhattacharjee, 2011, p. 3)

Some commentators have suggested that Prasher’s exit from science was due to a combination of bad luck and poor networking; according to Bhattacharjee (2011) he was successful only at gaining initial, but not later, funding for his research; as one of only a very small number of molecular biologists at his research institute he was intellectually isolated and under-resourced; and, although he wanted to stay working within the field, he experienced poor timing when trying to make initial contact with potential mentors including Chalfie. However, it’s clear that other factors were also at play – for example, timing and geography. Prasher had a young family, which made interstate relocation for the sake of his career more difficult. Furthermore, emotional characteristics such as a high degree of personal pride, or “being German and being stubborn” as Prasher has reportedly described himself (Grant, 2013) may have prevented him from asking for help and building more positive networks.

It is interesting to note that after being publicly recognised by the Nobel Laureates for the seminal role that he had played in the discovery of GFP, Prasher’s tale received widespread media coverage, and in its wake new job offers and successful funding applications have followed; Prasher is now employed as an associate researcher in Tsien’s lab where he is once again working at the forefront of GFP research (Grant, 2013). One thing that is apparent in both the cases of Douglas Prasher and Robert Winston is the important role that both communication and professional networking seems to play in making – or breaking – a successful career.

**Communicating results**

Effective professional and interpersonal communication were commonly cited at interview as contributing factors to success, and many participants identified
presenting and publishing results as a primary mechanism by which they had begun to achieve this. Some felt that publishing had ensured that they received attention from others and opened the doors for further opportunities, propelling them in the right direction for a successful science career. Regarding the direct benefits of publication, the Nobel Laureate Peter Doherty observed:

(Scientists) need to learn to write properly... and they have to get out there and talk to their colleagues, attend international conferences and push themselves forward. Don’t be afraid to make mistakes, you need to get known in your field in order to stay in it...you need to build up a reputation... There are bigger research teams working on problems, and it’s getting harder to differentiate yourself from all the other researchers working in your group. Some of these groups are so big that you can have dozens of authors on the same paper, and the young researcher can appear way down on the list...

For some interviewees, the opportunity to publish as a lead author and subsequently gain a sense of identity as an expert in their own right was a particular point of pride. For example, as the virologist Frank Fenner described:

Burnet was a dominating scientist, in the sense that when he was working on influenza he wanted virtually everybody in the Institute – which was very small, about the size of a department in most places – to work on influenza. But he appointed me to work on this different thing and he gave me a completely free go. All the papers I wrote on that were under my own authorship, without Burnet as a tag-on. Our discussions were such that when I had a paper written I’d take it along to him, he’d go over it that night (as) he used to work in the lab all day, and we’d discuss it next morning, together with what to go on with next. So he gave me a very free go...

Fenner’s account records his delight at publishing under his own authorship, albeit under the benign tutelage of Burnet. However within the interviews there was also evidence that publishing was not always guaranteed to be a positive
experience – some felt that the processes of peer review could be turned against the individual to make or break a scientific career. For example, one interviewee, who requested anonymity in the following account, described the “nastiness” he witnessed during his postgraduate years in a ground-breaking new area of research:

My supervisor, S, was the first to recognize (an interaction) that redefined the problem... He and the group had an idea of how it might happen and that’s what I worked on for my thesis... And unfortunately what I discovered is that idea didn’t work.

Meanwhile X and Y had produced a better idea... and they had managed to block S’s publication through taking 18 months to review it and then rejecting the paper. It wasn’t right, anyhow – but they never cited his work and it’s a fact now that these things are named after Y. If justice had happened... then the Nobel prize should have been shared with S, for redefining the problem.

In his interview, the scientist’s sense of outrage at this event was palpable: he clearly felt that his supervisor had deserved equal recognition for contributing to a significant discovery but had been cheated of success through the underhanded stalling techniques of competitive colleagues, who wielded power by being the first to review the original findings. In this particular account there was also a sense of the potential repercussions that the supervisor’s failure might have had on the young scientist. He recalled suddenly realising that the association might taint his own career, and ‘hastily’ wrote up his results in order to seek a post-doctoral position at another laboratory. Another reputable scientist, acquainted with the supervisor S, subsequently facilitated the student’s progress into a new research environment.

This account and others like it give a sense of the important professional and social relationship that may exist between graduate students and their supervisors. In some cases, interviewees suggested that this relationship persisted over many years, with many reporting that their doctoral supervisors had initially...
been important role models, mentors and in some cases, heroes, before becoming peers, colleagues and friends with whom they remained connected. Such enduring experiences are reminiscent of Stephen Jay Gould’s reflection on his graduate supervisor, Newell, who as reported previously had also mentored the young Mike Archer:

The work of graduate students is part of a mentor’s reputation forever, because we trace intellectual lineages in this manner. I was Norman Newell’s student, and everything that I ever do, as long as I live, will be read as his legacy. (Gould, 1989, p. 140)

Gould suggests that his own achievements are also Newell’s – in short, that the two are inextricably linked. And such comments are supported by examples given at interview, which suggest that intellectual lineages and professional interconnections are an important feature of a science hero’s pedigree.

**Lineage**

Many participants described having a strong sense of support from and connection with their graduate supervisors and senior colleagues, particularly those encountered within the research environments and professional networks of their postgraduate years, whilst they were still undergoing training in the essential skills and attributes of their disciplines. Many felt that they had developed key skills and important professional connections through their supervisors and mentors.

Several of the interviewees suggested that senior scientists had actively selected them as protégés on the basis that they displayed existing skills and had a good likelihood of achieving success within their laboratories. For example, Frank Fenner recalled being invited, as a young scientist, to visit the Walter and Eliza Hall Institute (WEHI) in Melbourne. According to his account, the Institute’s director, Frank Macfarlane Burnet, had already ‘sounded out’ referees regarding his skills and credentials. Fenner felt that throughout his first visit to WEHI, Burnet had been testing his aptitude and cultural fit, in order “to see whether I
should join them” before a fellowship was formally offered. The strong suggestion was that Burnet selectively recruited for both technical skills and personal attributes in his future employees.

This suggestion is supported by the account given by Gus Nossal, as described in Chapter 4, who also felt that his own success was honed by exposure to the thinking, working and communication styles of the great scientists at WEHI, including Burnet. Nossal’s own prolific career path closely mirrors that of Burnet; like his mentor, Nossal would become the Director of WEHI and Professor of Medical Biology at the University of Melbourne, publishing multiple books and hundreds of scientific articles en route (Mellor, 2008). And following in his footsteps would be the renowned epidemiologist, Fiona Stanley, who at interview observed that Nossal “has been more than a role model – he’s been a mentor”.

The qualities for success that Nossal himself described at interview would again be made available to a new generation, through Stanley who was recognised for her achievements in 2003 as Australian of The Year. As quoted in Lewis (2010), Stanley has said:

Gus Nossal once said to me that one of the most important characteristics of an institute director was generosity. He’s absolutely right. I think that one of the things I am good at as an institute director is being generous. And that means being generous with your time. Taking time out to mentor our young Aboriginal researchers is really important, taking time to find out about what is happening to people in the Institute and where they are going – it takes time to be generous.

From such accounts, the investment of time appears to be carefully considered with respect to how the recipients will maximize their talents and skills to bring future rewards in the form of both scientific excellence and over-arching organizational and social outcomes.

Another interesting example of lineages emerging within the study was documented within the account of geochemist Larry Edwards, who said:
It's interesting that I ended up at Caltech working with Gerry Wasserburg. I first learned about him because I was up in the National Falls in the middle of the wilderness and one of my co-workers subscribed to some kind of magazine... There was this article of Gerry Wasserburg in there and that's the first I'd heard of this guy. They're talking about him and his clean room, and he's basically analysing stardust, and I thought this is really interesting! How the universe started and how the solar system started and he's working on questions like that. I thought this is really interesting and this guy is really doing interesting work. But I just had it in the back of my mind at that time. And then later on I ended up at Caltech and so I looked him up... I ended up working with Gerry and he's really quite – he is really something... he's just this incredible scientist... I really look up to him in that regard. At the time, I'd realised that right away... he just really knows how to do science and he knows how to do important science... so when I ended up working with him I really looked up to him because he was such a clear thinker and also worked on important problems... We're really very much on the same page in that regard, I mean in terms of kind of big problems and I think thinking clearly and thinking in very fundamental terms. Our big connection was there... Somehow we really clicked and have managed to keep a really good relationship with each other for many, many years and that's really been wonderful.

Edwards' account suggests that the superior reputation and skills of his mentor were factors in his career choices; despite coming to Caltech for other reasons he would soon find himself drawn to and working closely with Wasserburg, in a process reminiscent of the latter's own journey to becoming 'a good horse from a good stable'. And clearly, a mentor's well-timed advice about career choices can have positive and profound effects; as Wasserburg recalled his own success had depended, in part, on taking a key piece of advice from one of his own mentors:

When you're young you want to establish yourself. You want to do something important... I went to Harold Urey's office, I decided I was
going to do a thesis with him. He said, ‘well young man, I think you should measure the potassium-40 argon-40 ages of meteorites’... Well, that helped me open up a whole new field. So being in a place where somebody who is very smart pointed me in a direction was a hell of a big help...

When I finished my thesis it was a very good thesis. It was very short and very important. Lots of insightful and careful and meticulous experiments... and everybody said what a great guy I was, they gave me a research fellowship to the Institute for Nuclear Studies...(then) I get a phone call from my friend George West Wetherill, who'd gone off to Carnegie Institute in Washington. He said ‘the conclusions of your thesis are wrong!' ‘Ha ha ha’, I said, ‘what?’ ‘It was really done meticulously but it was based on one assumption. That assumption was not true.’

So when I get off the floor, I went to see Harold Clayton Urey and I said ‘Professor Urey I've just got this message that the conclusion...is not correct. That is in fact true. What should I do?’ He looked at me. He said ‘young man, if you're on the wrong train I advise you to get off of that train as rapidly as possible and get on the right one'.

Wasserburg’s account suggests that Urey’s advice and mentorship was crucial to helping him successfully navigate such challenges. In addition it indicates that intellectual lineages can be long-lasting, mutually supportive and extremely useful throughout a career. Indeed, in Wasserburg’s case he went on to co-publish a paper with Wetherill that clarified the error, and the two subsequently maintained a long professional relationship (Marvin, 2004).

From many interviews, an impression was gained of an almost continual mentoring and development process in science that is capable of bringing important benefits to both mentors and mentees. A picture clearly emerged of ambitious young protégées, possessing both talent and skill, seeking out more established, successful, and well-connected leaders in their fields. By doing so, they acknowledged gaining access to new opportunities to expand their
capabilities and professional influence, and to be involved in important work that would position them at the forefront of their fields.

It was also apparent that by so doing, the mentor would ultimately share in the reputational spoils that followed. For example, as Edwards carved out his own niche at the forefront of climate science, some of the acknowledgement for this work would be shared with mentors such as Broecker and Wasserburg. Accolades would flow to all of them, and over time reputations would be mutually enhanced. As the ‘Grandfather of Climate Change’, Wally Broecker, proudly said of protégé, Larry Edwards:

He has a paper in Science this week, which is a colossal paper in that he shows an amazing thing. He can date stalagmites to one year in the last couple thousand years. Yeah, one year experimental accuracy – he’s probably very close. One of the things he’s used it for is that in Chinese caves, the isotopic composition is a measure of the strength of the monsoons. He shows in this paper that three, I think, or maybe four of the Chinese dynasties came to an end during times - 10-year periods of weak monsoons. So in other words, people were starving, so they threw out the government. Then the new government came in and the drought didn’t last all that long, so they looked real good. It’s incredible.

For those in later career stages who occupy positions at the very top of the lineal tree, looking back down the chain of influence and success is evidently a pleasurable experience. A further account by Wasserburg (2008), then aged 81, casts some further light on the benefits in mentoring others:

I have had the privilege and pleasure of working with brilliant, dedicated young people who interact with me, discuss with me, argue with me, criticize me, tolerate me, and work toward trying to understand something of interest in nature. It is this lust for trying, often very hard, to understand something of nature that is the driving force. The idea that maybe, maybe, I will understand something gives me a high, even if it is
not new. If I hope that it is really something new, then I am elated! The interrelationship between 18 and 81 is not just a switch of digits. It is the interplay between interested players of different ages and vitalities and skills, dedicated to trying to understand. That is both exciting and rejuvenating. It is my belief that whatever I am working on right now is the most important thing I ever did. I recently sent an e-mail to my colleague Yong-Zhong Qian in Minnesota about a possible new project.

He responded, 'We just got the proofs of our article; let us get that finished. Then we can talk about a grand new adventure.' The new problem is always the most exciting problem. I have had the privilege of working with brilliant young people who play that game. It is continuing this activity that keeps part of me always closer to 18 than to 81. That is the fountain of youth—drink from it! (Wasserburg, 2008, p. np)

Taken together, the accounts of Wasserburg, Broecker and Edwards create an impression of scientific reputations developing over time, built on a foundation of talent in which mentoring individuals retain a strong interest. By sharing their professional and intellectual networks with those of similar ability, individuals ensure that their work, reputation and knowledge is transmitted through the previous and subsequent generations.

**Exposure to greats**

Another technique reportedly used by mentors in the pursuit of success was to introduce their protégés to other 'superstars' in the field – more advanced scientists whose presence could create a sense of inspiration and excitement. For example, the geneticist Jim Peacock recalled how his postdoctoral mentor, Ed Novitski, had provided him with exposure to some of the superstars in his field:

Novitski gave me complete freedom. And, first of all, in what I would say was one of the most idyllic six months of my life academically, he brought me into *Drosophila* genetics up to the highest level, so that I was accepted almost immediately by all the top guns in the field as being able to talk
sensibly with them. I hadn’t at that time done any work in the field, but I really understood it and knew all the problems. He was just fabulous in that way. Every day he’d take me further, and give me papers to read.

(Peacock, 2008)

Similarly, the virologist Fenner described the experience of working under his post-doctoral supervisor, Rene Dubos:

At that time the Rockefeller Institute had a dining room to which all members of staff and all post-doctormen went down to have lunch...Dubos used to move with his post-docs from one table to the other, introducing us to all the notables. So we talked to Van Slyke, Tom Rivers, Frank Horsfall and all these great names; I met Albert Sabin for the first time there. Dubos deliberately went round and exposed us to all these different people, so you really got to know a lot of them and were able to measure yourself against the great figures in the scientific world. (Fenner, 1992-3)

Such accounts hint at the value of having access to established scientists as a source of role modelling and inspiration, and as a point of comparison for one’s own achievements. In Fenner’s case, it also suggests the importance that was placed by Dubos on understanding one’s scientific lineage and the inspirational role of those ‘great figures’ whose success had helped to shape and drive a field forward.

**Competitiveness**

Such accounts are also consistent with evidence discussed in Chapter 4, which suggested that many people viewed science as an enjoyable and competitive pursuit, in which they personally held a stake. In addition, within the interviews there was also clear evidence of competitiveness between science institutions, which reportedly vied with one another to attract successful research communities to either put or keep the institution on the map.
Yet despite the many benefits evident to institutions in the form of new students, highly cited publications, the likelihood of prizes or accolades and increased political influence, the success of a popular laboratory did not necessarily always create goodwill between colleagues within the institution. Instead, as some of the interviews showed, a highly successful laboratory or research group could create tensions between individuals and other groups of researchers. For example, one participant recalled that whilst successful grant applications enabled him to ‘pick and choose’ an institution, colleagues could also form resentments against a newly formed research group:

As soon as I got the funding...then I was able to establish a lab... If you came in at midnight it would be filled with students. The students were there not because I said ‘you’ve got to work at night’ but because I was there. It was a very, very exciting time... We were like this separate little group that was going full blast. First of all, this is 1962 or '63...people still wore jackets and ties, I didn't. People called their professors, ‘Dr So-and-So’, my kids all called me by my first name... Part of the problem was, as long as I had my funding, I had my group; I didn't really care about what went on in the department... I knew that if I got fired I could go anywhere I wanted, so I didn't worry... But it was a kind of separation – we had our own parties. We went to the bar drinking and we acted like this unit, which was outside the department. So I can see that people resented that.

Similarly, another interviewee described the experience of running a successful research laboratory within a major US institution:

I got a postdoc and then I came down here and asked the director for a position. I got a job but only for nine months, at the lowest possible level...I was absolutely paranoid because everyone was saying to me ‘what are you doing next year? your money runs out in 4 months’, so I embarked upon a campaign to write grants and build a program... I squeaked by, for 17 years I was completely self-funded, and had 12 people I was paying as well. Ultimately I said ‘I think I’m going to leave this place because
everyone else is getting all these resources and I’m not getting a thing’ and they didn’t like that, so they came to me and said ‘we ought to give you something significant’. That’s the way life is, you have to extort people... I forced the issue, and I was given an appropriate position and then it has appropriately increased in stature ever since.

Such reports suggest that the politics within institutions can be difficult to navigate, and that work cultures introduced by outsiders may come into conflict with the existing cultural norms within organisations. Despite the benefits to the institution overall of employing successful individuals, to those already established within the culture, it also appears that the arrival of a new player may also pose something of a threat. One participant also described how colleagues sought to undermine his newly-established research group:

Very, very few of them would ever say anything to my face. It used to make me absolutely livid, that my students would be the ones that got criticised for me. You know, if people didn't like what I was doing why wouldn't they come and tell me to my face?

Communities of practice

The accounts also suggest that the recruitment of successful leaders and formation of new research laboratories creates opportunities for career advancement amongst those who join the group. When new fields of research open up, the forerunners apparently exert control over the culture by selecting who else joins the team. Interviewees who had led such groups suggested that they looked for traits such as intellect, ability to function within the research area and ability to strengthen the networks on which the research area depended. For example, as Fraser Mustard described:

When I was setting up the Institute and its programs I interviewed everybody... to see how easily they would fit in, to developing interactions with others, to advance knowledge...and made a judgement call as to whether they would or not be able to function...in an interdisciplinary
world. My satisfaction is being able to...get things produced because you can get that interaction amongst the people.

From such statements a picture emerges of the importance placed on communication skills within the research environment, and of researchers working not in isolation but deeply embedded within social networks and communication cultures, that inform and strengthen their work and that help to create new connections and spheres of influence. As Nobel Laureate Peter Doherty recalled:

Somebody who did have a profound influence on me was Cedric Mims. He was in my own field, and kept on producing interesting things. I was very influenced by reading his work, rather than by direct contact with him. In fact I came back to Australia and then to the Australian National University because of him. Actually it led to me taking up his lab...

Doherty’s statement succinctly conveys a sense expressed by many others at interview, of highly achieving individuals in a field attracting and developing further generations of talent; some also described how their mentees would ‘rush up’ to share newfound knowledge or information with them. However as the following section shows, those approaching their heroes were not only those who strove to enter the same professional sphere, but people from all walks of life. From the accounts given at interview, it was clear that science heroes experienced a very diverse array of responses to and consequences of their perceived influence.

5.3 The consequences of fame

On being asked to reflect on his experiences of fame, one participant said:

Let’s say that I’m relatively well known. It’s very embarrassing to be picking up your groceries at Safeways and have someone say ‘oh gee I love your work, oh gee keep it up’, you know? And let’s be quite frank. This is really quite irritating to one’s family. I mean the grand kids want a grand
dad, they don’t want someone who is a pop star. I mean, it is not a big deal because they know themselves that I don’t have tickets on myself, and that it doesn’t obtrude in a major way. But in a minor sort of way it’s an irritation. It’s nice to be able to catch the tram downtown and not have someone staring at you and say, ‘don’t I know you?’ Often people won’t quite know who you are but they know they’ve seen you, ‘sometime, somewhere, but just remind me?’…It’s irritating...

Many participants shared similar stories of being approached by people they did not know, and analysis of these accounts revealed a startling array of contexts and motivations behind the approaches made. It appeared that complete strangers, who presumably knew of them only through their publications or talks, appearances in the media, or by word of mouth, felt both compelled and comfortable enough to strike up a conversation with somebody who, on the face of it, they barely knew.

Such behaviour has striking parallels to the behaviour of fans towards other sorts of celebrities, such as film stars. Indeed, the study included several participants who were TV stars, including The Mythbusters, Adam Savage and Jamie Hyneman. Incidentally, the behaviour of fans towards the pair was recorded during the course of an interview that took place at a pub in an industrial area of San Francisco. The participants, wearing their trademark attire of a black beret and walrus moustache (Jamie) and black roll-neck sweater (Adam) were clearly identifiable. As the following interview transcript reveals, the conversation was interrupted just as it drew to a close:

Adam: We have to get back to the shop (pushing chair back)

Jamie: (Finishing conversation) It was 28 pounds. So that visualization, that’s the thrill. We really like that, just because it’s just such a classic of...

Fan 1: Hey, you guys, would we be able to get a picture with you guys?

Jamie: Sure
Fan 1 (to his mom): That’d be cool?

Mom: Yes

Fan 1: That’s a very good outcome for people. Awesome. This is my mom, Roseanne.

Mom: Nice to meet you

Adam: Hello

Fan 1: This is my great mate Dustin.

Dustin: Hi

Jamie: How you going

Fan 2 (passing by): Hey boys. Great stuff.

(First fan group takes photo; mom is hurrying them up, a bit embarrassed)

Fan’s mom: Thank you guys

Adam: You’re very welcome

Fan 1: Thank you...you guys have a good night, I love your show

Jamie: Thank you

Later, in the car:

Adam: Most people, most of the time it’s like that, most people actually do wait until we’re done eating. I hate those people who interrupt me in the middle of a bite. It gets a little exhausting.

This exchange documents certain behaviours on the part of both fans and celebrities, who in this case seemed to interact as if by mutual agreement: in their manner of dress, Adam and Jamie clearly signalled that they were indeed the Mythbusters; strangers, encountering them for the first time, rushed up to touch them, talk to them and then carry away a memento; and all the while, seasoned
bar staff regarded the star duo as simply another regular customer. Two very
different responses to the science hero were thus observed within a public
environment, and further analysis of the interviews showed that there were in
fact many different responses elicited from those who encountered our science
heroes in the courses of their lives.

At interview, participants were also asked about their experiences of interacting
with the public and how audiences responded to them. The results showed that a
diverse range of interactions had taken place, within many different settings,
which included:

- Public engagement settings, where individuals had sought out of clearly
  made themselves available for direct interactions with audiences. Examples
  included giving public talks or lectures and participating in other types of
  public event, such as science festivals.

- Private activities, where individuals felt that whilst they had neither
  invited nor encouraged any contact, they had nevertheless been
  approached and engaged in a conversation of some sort.

- Private correspondence, where unsolicited written or verbal contact was
  received from audiences. This correspondence took every conceivable
  form, including postcards, letters and parcels, emails, phone calls and
  personal visits or meetings.

For interactions reported within public engagement settings, participants
identified a degree of ‘give and take’ in their relationship with their audiences.
This was primarily through providing opportunities for questioning and engaging
in conversation. As Ron Oxburgh explained of his audiences’ responses to his
public presentations:

(People) want to come up and talk afterwards and they generally seem
excited and stimulated and have a generally positive impression... when I
talk to people I would say about 98 per cent say, ‘gosh I hadn't thought of it that way, yes you're right’. I guess that if I wasn't getting that kind of response I would be worried.

Similarly, Bryan Gaensler described feeling an obligation to the audience to meet their expectations and create an environment in which genuine interaction could take place:

I think you've absolutely got to be prepared to take questions... Because there's always going to be a few people who just come along just to ask that one question and it's incredibly personally disappointing for them if they don't get to engage you. And some people often just want to see how you respond to crazy questions, they say 'I've got a question and I know it's really hard, like what was there before the universe?' and part of, for them, their assessment of your credibility is how well you deal with their questions. Because I've seen it, some people will just ask the same question of every speaker. I won't even mention black holes and they'll say 'tell me about black holes'.

Now (for) some people in the audience the credibility just is there and they're not worried, but other people want to see you engage and respond. It's not very rewarding for them just to see something that they could have watched on YouTube, they want a chance to engage. So I also encourage questions during the talk... there's always, for every person who asks a question, there's going to be five others who thought about it but were too nervous or shy to ask.

Gaensler's account suggests that his audiences are very diverse in terms of their needs and may have a range of motivations for attending his talks. Amongst these is a desire for information, whether seeking to learn something new or to have pre-existing ideas and knowledge further extended. There are also emotional elements at play in Gaensler's account; one suggestion is that audiences have a desire to actively experience, engage or interact with the speaker, in ways that are unavailable through other mediums such as video. There is also a sense that
audiences want to ‘believe in’ the speaker and have confidence in their credibility.

Many participants recalled specific examples of conversations they had had with members of their audience either during or immediately after such events, where people most commonly sought to discuss the key issues or ideas raised in the presentation. For example, as Jocelyn Bell Burnell reported:

I’ve found it after a talk I’ve given, if I’ve got a chair who will let the questions run... it starts off with the clever geeks asking questions, for which they don't want answers, they just want to show off how clever they are. And then you get still somewhat geekish questions but they want the answers. And then somebody says 'what’s it actually like being an astronomer and observing at night?’ you know, 'tell us about your night, what it’s actually like.' And then it gets more and more, and the women begin to chime in at this stage; 'how do you reconcile that with having a family?' And if it goes on, and sometimes with a good Chair, it will go on for about an hour and a half after the lecture, it finally gets around to God and the meaning of life and the universe.

Some people expressed the feeling that once they were recognised ‘on the street’ they had no choice but to engage, particularly if the person approaching them had something positive to say. For example, as the entertainer, Johnny Ball recalled:

People come up to me today, very frequently and say, ‘I’m an engineer because of you’. ‘Are you?’ ‘Oh yeah, yeah!’ ...I was at Brighton races and two fellows came up and they were about 33 or four or five and they were in very smart suits, decent suits and they’d had a few ales, half past three in the afternoon at the race day. One says, ‘I’m a nuclear physicist because of you’. His mate said, ‘you influenced me too’. I said, ‘what are you?’ He said, ‘I’m a bookmaker’! It was wonderful that those two people that had
taken two completely different directions and they remember, with such affection.

Almost all participants in the study reported receiving correspondence from diverse audiences, and the amount of correspondence received seemed to vary with the degree of fame and public exposure the individual had achieved. For instance, those with a high media profile reported receiving very large amounts of correspondence, in some cases numbering many hundreds of separate items daily, which ‘spiked’ immediately after a program was broadcast. Whilst some proportion of this correspondence was reportedly from scientific colleagues and peers, and from PR companies or institutions wanting to recruit them for various causes, the vast majority of correspondence was reportedly received from members of the public.

The science broadcaster, Robyn Williams described some of the challenges and pressures associated with responding to the volumes of correspondence he received:

There are hundreds of different messages; it's now almost impossible to keep up with the spray of stuff, and you don't know what is reflective and personal and what is simply material that's chucked out (at you). And we used to get lots of hand-written or typed letters, and of course these days there's fewer of them, and so you're left with emails. I do two or three programs and each one has its own website – and so you get emails for them, you get the online site, and you also get your personal emails where people find your address and get in touch. So it means that communication between broadcaster and listener – member of the audience – is quite different. There's less courtesy – people just bung their opinion, sometimes very tersely, sometimes in a way that's rather bizarre – you know when I did something about the Twin Towers in New York last September, I actually for months got material obviously from an organised website, and collection of people who are linked to each other, telling me that it wasn't the planes, it was the CIA or someone. So you get plenty of
those, and if you mention global warming there’s a similar kind of network
pushing the line that that’s all crap. So the Internet has meant that people
can communicate at you without even straining their little fingers, it’s so
easy. But I still take a huge amount of notice of people who send messages
that are plainly thoughtful, and they’re constant listeners, and I really
treasure those. I respond to all of them. There’s no choice: you either do it
as a discipline or you lose track... And the question of overload is constant,
really.

Participants were also asked to characterize the correspondence they received
from members of their audiences, and their descriptions yielded fascinating
information about the nature of the relationships and interactions people were
seeking. Further analysis enabled the types of interactions experienced by
participants to be summarized as follows:

**Personal acknowledgement**

In many cases, individuals received positive acknowledgements for their work,
with instances including statements of:

- Admiration; e.g. “I really like your work”
- Respect; e.g. “I was very impressed by your talk”
- Gratitude; e.g. “Thank you for discovering something of importance”
- Modelling; e.g. “I want to become a scientist because of you”

Many media personalities recalled hearing from audience members that they had
been a source of inspiration. As entertainer Johnny Ball recalled of the public
response to his television show *Think Of A Number:*
The letters started coming saying, ‘I'm going to be a mathematician because of you, I'm going to be a scientist because of you’. The hair went up on the back of my neck because I have no qualifications...

Individuals also reported receiving expressions of gratitude for their contributions at different levels of society, including to the life of the correspondent, ‘for the nation’, or to the wider scientific and social enterprise. In some cases these were accompanied by gifts, such as drawings by children, or through more formal acknowledgements, such as having facilities named after them or receiving complimentary qualifications from universities.

**Information-seeking**

In a number of examples given at interview, audience interactions included requests for information. Examples of information-seeking requests could be categorized as:

- Opinion-forming; e.g. “What do you think of X?”
- Confiding; e.g. “I have experienced a problem, P; it would help me to know more about it”
- Advice-seeking; e.g. “What should I do if I want to achieve Z?”
- Knowledge furtherance; e.g. “You mentioned X, what can you tell me about it...?”

Such examples seemed to suggest that the individual was seen as a trusted expert and a repository of knowledge seen as being particularly useful to the correspondent.

**Physical proximity**
In some cases, participants reported audience members seeking to establish a personal connection through making or requesting physical contact; handshakes were reasonably common, but other forms of contact were also requisitioned, including kisses and hugs. Participants also reported people requesting physical mementoes such as autographs and photographs.

It seems that many friends and acquaintances of the interviewer also sought physical contact with participants of the study; on completion of interviews with particularly well-known people, I fielded numerous questions along the lines of “what was he really like?” and “did you touch him?”

**Invitations**

Individuals reported being invited to participate in a wide range of further communication activities including making public appearances, giving media interviews, leading, patronising or otherwise supporting the cause of organizations and groups, reading or authoring publications, providing advice, appearing on or leading committees and participating in studies such as this one. Individuals were also occasionally invited to attend personal events, such as birthday parties, or to become involved in intimate relationships.

**Enquiries**

Many interviewees received enquiries about aspects of their work, often from individuals seeking expert advice on various issues. These enquiries included requests for

- Practical guidance about how to do something the interviewee had spoken about or demonstrated. For example, some interviewees reported people wanting further instructions for making a working model or seeking advice about what steps to take to get onto a particular career path modelled by the interviewee.
• Reference resources or further sources of information about something the interviewee had communicated about. For example, if the interviewee had given a presentation on climate science, somebody might request the details of a particular report or seek a list of further reading.

• Answers to homework questions, usually sought by students or by parents who were making enquiries on behalf of their children. Some interviewees reported whole classes writing them letters containing questions that had been discussed or set in the classroom.

• Scientific identification or verification, from individuals seeking confirmation of a scientific idea, theory, discovery, possible patent application or innovative process. In some cases, interviewees were sent unsolicited mail containing samples, models, photographs or plans of an invention, for review. In some cases, they were asked for help to progress the invention or idea to the next stage, such as carrying out confirmation testing.

Requests for advice were also frequently reported, and the topics on which advice was most commonly sought included:

• Careers – different forms of careers advice were sought, including advice on how to join or succeed in the profession of the interviewee. In many cases, the advice was sought by those wanting to follow a similar career trajectory. In some cases the advice was sought on behalf of others, for example by parents or other relatives enquiring on behalf of their child, including those attending university.

• Health – some interviewees, particularly those with a medical background, were asked to diagnose illnesses or provide personal health advice. In some cases, this advice was being requested on behalf of others, such as an ill relative or friend. In one case, an interviewee reported presenting a public lecture about brain injury, to which “hundreds of
people turned up with their CT scans, wanting me to look at them, which I had to say I couldn’t.”

- Discoveries – some interviewees were approached for advice about how to validate or patent an invention or discovery. In some cases, interviewees were provided with the details of discoveries and asked to keep them secret until they could be validated. A share in the spoils was sometimes promised as part of such requests. Interviewees considered many of these to be ‘crackpot’; either not entirely rational or lucid, informed by conspiracy theories, or seeking financial advantage. Discoveries of perpetual motion or infinite energy machines were frequently cited; other examples included the submission of samples of a ‘rare material’ found in someone’s backyard, and in one case an enquiry seeking confirmation that drinking the urine of virgins could promote good health.

Whilst many relevant examples of such ‘discoveries’ were provided at interview, perhaps the most succinct explorations of these came from science broadcasters, who typically received very large volumes of unsolicited correspondence. For example, Karl Kruszelnicki characterised his ‘crank’ callers and those seeking confirmation of discoveries thus:

About once a week somebody walks into this office and they’re really smart and they’ve got a crackpot theory...nearly half of the time about Einstein... there’s people who’ve got their perpetual motion machines, or the proof that the plane that went down in the Hudson River was actually all a big conspiracy: flight 1549, what happened in ‘49? The Freemasons had their big meeting and the aeroplane took off from La Guardia airport, and La Guardia was a 33rd level Mason - the mayor of New York. And it was near Highway 33... So there's people like that, with their crackpot number theories. And then there’s people who’ve made small discoveries and are incredibly amazed by it... And they’re saying ‘but nobody knows, we’ve got to tell everybody!’...And then the UFO ones – don’t forget the UFO ones!
In some cases, ‘crackpot’ correspondence can continue over long periods, or raise concerns in the recipient as to the welfare or intentions of the correspondent. For example, as the physician and philosopher, Ray Tallis recalled:

There are some people who send you absolutely batty things. I’ve had a mass of correspondence from a lady who discovered the secret of the universe in 1973… and those things are quite worrying when they have an evangelistic aim and they think that if they can convert you then you’ll stand on the podium and you will spread their views. In a sense, you become a loudspeaker for their views and that’s the ones where you have a lot of cut and paste things and old typewriters used - you know the "o"s are filled in with a bit of ribbon and so on. And then you get quite worried because you think (a) they are potentially very vulnerable and (b) potentially a bit dangerous - you don't know; you've got to be a bit careful.

Whilst Tallis’ experience suggests that some individuals correspond in order to gain support for their ideas, other participants described the wide variety of correspondence they received more often expressing themes of gratitude, curiosity and information seeking. One particular extract from the broadcaster, David Attenborough highlights several of the recurring themes identified in the accounts given at interview:

The interesting thing is that you get a letter. And I remember a particular occasion, when I had letter from a child aged 7 saying they thought it was a wonderful program; the very next day there was a letter from the professor, actually from a British university, I suppose aged about 57, saying exactly the same thing but in his phraseology… I suppose a more meaningful reaction that one gets is that, since I have been doing it so long and still get around a bit, I am constantly meeting people who say ‘I would never have gone into biology had I not seen the sort of programs you make’. And of course that is very touching… I think it's very important to respond to letters and particularly children’s letters. You know, I had a charming one this morning. ‘How do you know that a whale's tongue
weighs half a tonne?’ says this child. Good question and betrays a proper skeptical mind, and in this, today’s climate, killing whales seems insupportable and of course I shall reply this afternoon and say ‘well in times when we didn’t know better we were continually killing whales, so there were plenty of whales tongues to weigh’.

I get a huge number. I mean people send you plenty of things, they send you fossils, they send you mangled remains of butterflies, they send you the indecipherable! Well yesterday I had this photo: ‘We saw this in Alaska, it’s a dragonfly, can you tell me what species it is?’ and if it’s a pin prick over a vast lake scape – yes, well a pin prick would be bigger I would think! It’s tiny, I mean ludicrous. Nonetheless, that’s what you get.

As exemplified in Attenborough’s account, the desire to ‘reach out’ and engage with one’s science heroes is a behaviour not restricted just to the young; as many participants similarly pointed out, correspondence arrives from people of all ages and all walks of life, whose interests range from quite general expressions of admiration or enjoyment to very specific questions that relate to particular informational needs. As suggested by Attenborough’s example of the child and the professor, enjoyment in Attenborough’s work appears independent of age, level of education and degree of scientific knowledge; to these viewers his program is ‘just wonderful’, and his fans have no hesitation in reaching out to tell him so.

Importantly, Attenborough’s account – like many others given at interview – also conveys a sense of curiosity about the world that seems to percolate through the minds of his audiences. In the asking of questions and the presentation of evidence requiring confirmation, there is a sense that he is both a broker of and repository for knowledge – a trusted expert who knows everything about the living world, and in whom trust is placed to come up with the right answer.

Clearly, to some audience members Attenborough is also an inspirational role model; his account of ‘constantly’ meeting such individuals suggests not only that the numbers of such people are significant, but they are grateful for his influence
and wish to tell him so. Certainly, anecdotal evidence from other parts of his account suggests that a chance to enter Attenborough’s world is perceived as an incredible opportunity; as he later revealed, over 3000 applicants applied for one public advertisement to work as a researcher in the BBC Natural History Unit, the majority of whom were doctoral researchers. And like Attenborough, whilst most participants felt that the tone of approaches from their audiences was largely positive, in many other instances unsolicited criticism was also reported.

Compliments and criticism

Individuals reported receiving unsolicited feedback about many aspects of their performance. Such comments often appeared to be focused on the content of their work and areas of expertise, with a major focus on the individual’s factual accuracy and/or reasoning. As Ken Calman reported:

People get quite personal about things sometimes, which it’s not a pleasant thing to be. I don’t know how politicians stand it. Sometimes it’s actually quite negative about you and what you’ve said and done, but then I think that’s part of the job. The key thing, I think, is to be as true to yourself as you possibly can... The worst thing, which is a new phenomenon, really, are the blogs. The blogs are sometimes malicious and vindictive, because people can write things about you and you don’t really know who they are. It’s really very interesting to read these. I can’t stand it at times, I just put them down, it’s so horrible... and because there’s not a way of replying really, it’s an easy way of people being able to say things without in a sense, the right of response.

Such reports suggest that comments made about those in the public eye can be highly personal. From other accounts given, it also appeared that criticisms could be incurred for a wide spectrum of ‘faults’ that included physical appearance, race, gender, sexuality and other personal characteristics. In one such example, the broadcaster Adam Hart-Davis reported receiving letters of complaint demanding to know why he ‘dressed like a clown’.
In some cases unsolicited criticisms were directed at the individual’s institution, peer group, or profession more generally, and these seemed to occur in response to issues that tend to polarize the public, such as those working in areas related to emerging biotechnology or the environment. As participants such as Gus Nossal reported, receiving ‘hate mail’ was par for the course:

I receive quite a bit of hate mail. The anti-vaccine activists, the people who hate genetically modified foods, even anti-nuclear activists. Now I’m very much anti-nuclear warfare myself, I’ve done a bit of work in that field. But I’m pro-nuclear energy for the world... So all of this engenders a certain degree of hate mail, they’re subjects that people feel very, very strongly about and some of them sometimes think that they know all about them too, but it’s not often the case. ‘These GMO's are going to kill you, you're going to have GM canola putting herbicide resistance into plants... and they’re going to destroy all the bees. The vaccines are going to give you autism and they are also going to give you multiple sclerosis’. But that is only a small proportion, a very small proportion of the overall correspondence.

Similarly, Anne Henderson Sellers reported experiencing backlash from members of the public, in the course of leading a working group for the Intergovernmental Panel on Climate Change. As she described of the reception for those involved in communicating climate science in the lead up to the COP15 meeting:

It hasn't been about expressing political opinion, just science. But it has been bloody. I’ve been targeted from time to time, when people think they can get some mileage out of it...in Copenhagen I was picking up my email on my iPhone and somebody was going on about sea level rise. I didn’t recognise the name, just some guy and I thought it must be somebody there at the conference...but it tuned out to be somebody from Australia who's picked up my name, realised I was there, and was having a go. And he was upset himself, something had happened, and he wasn’t allowed to build a house, he lived somewhere near the coast and he really wanted to
know whether that was right... but also he wanted someone in Copenhagen to go and tell the scientists who were saying this stuff, how much individual cost was involved and in his view increasing panic unnecessarily... It wasn't out-and-out bad, he had a view that I didn't agree with, and he had a view that his life and property value was being reduced because of people like me and all those other scientists who were there were saying this stuff which he wished we didn't. It's hard to answer someone like that. You can sympathise... this is just a regular bloke; yes he would have preferred us not to say it; he would have preferred not to know.

Such accounts suggest that there is a degree of active emotional engagement on the part of the audience that is sufficiently motivating to spur them to put pen to paper. Furthermore, within these accounts is an implicit sense of individuals within the audience who wish to engage in conversations or debates about topics in which they have a strong personal stake. Sometimes, it seems, public audiences feel that scientists may have missed the point or underestimated the importance of the information as it impacts on the real worlds in which they live.

For some interviewees, possible explanations proposed for these reactions included the public's lack of accurate knowledge about either the scientific facts or how scientific processes work, and the poor communication practices of some scientists. As the marine biologist, Usha Varanasi summarised:

There are definitely negative consequences of doing science, sometimes. Some people don’t want to find out, because it’s much better if you don’t. When your science comes out and if it’s not clearly explained to people what’s going on and it affects their livelihood – I’ve worked quite a lot, closely, with fishermen, fishing communities. I have gone and sat down with them and say: ‘why don’t you like some of the science we do?’ and then you’ll find out it’s not the science they don’t like. Sometimes they don’t know how we make it conclusive. Scientists quite often tend to be arrogant. They think fishermen can’t understand it. I tell you, people in
this land, can – even the most complex thing, when it affects their livelihood or their children.

Such accounts highlights the presence of the ‘deficit model’, which as numerous commentators including Bauer (2008) and Dickson (2005) have pointed out persists in many scientists’ views of how and why to communicate despite belying the complex societal dimensions of their work. In addition, Varanasi highlights the potential for arrogance – a form of social ineptness – on the part of scientists attempting to engage the public; she is not alone in this respect, with many other participants observing that the ‘social skills’ of their colleagues were lacking or their communication skills insufficient to create positive interactions with the public.

For those genuinely attempting to engage in conversations, being on the receiving end of criticism also appeared to have significant personal effects. In some cases individuals reported feeling frustrated and defensive whilst also expending considerable energy trying to communicate their point; for example, as Anne Henderson-Sellers observed:

Sometimes you get completely trapped; people actually send you wicked stuff, where you send them further information and it turns out they were just out to get you. You're trying to think and defend yourself a little bit and also defend the truth as you see it. And sometimes you think 'bugger it' and you just junk the lot because you haven't the energy any longer; you think 'I can't do this'.

Such accounts tally with widely circulating reports of scientists being maliciously targeted and receiving threats of physical harm in response to their work, such as those documented in relation to climate scientists (Clynes, 2012) and animal researchers (“Fighting animal rights terrorism,” 2006). Indeed, within the study several participants reported attracting significant degrees of public vitriol for speaking about highly contentious or politicised subjects. In addition to the many reports of ‘hate mail’, a small number of participants reported experiencing
even more extreme responses to their communication efforts. For example, as Helen Caldicott recalled:

I’m sure they thought of killing me, I had eight death threats, but then I would have been a martyr, so that wouldn’t have done them much good...I get some hate mail, not very often now but in the old days, in the 80s in the back of the audience there’d be these young guys in dark suits, who were evangelical Christians and they’d ask me if I believed in God and I’d say ‘it’s none of your business to know’, and rarely abortion would come up...I was seen as unpatriotic, and a threat to America’s very being. Mostly this came from men, the right wing was very strong in the 80s, and the think tanks were starting to operate very effectively...

Similarly, the former school teacher Howard Bennett recalled how he became a target for attack when lobbying for the clean up of Santa Monica Bay:

I had threats on my life when I was doing the Santa Monica Bay thing...they threatened (my wife) Bente’s life, so then I bought firearms...I thought that wasn’t fair, but...there’s no such thing as fair...I was asking them to spend, in this case, hundreds of millions of dollars. Over a billion dollars. Was I naive! What an idiot I was. But...that’s the way the cookie crumbles. If you’re not aware of that, you’re heading for a fall, big time. If you want to try and get into somebody’s pocket book, their money - all bets are off...you’re trying to change the status quo of business, and business is not afraid to do what it can to continue on. You’re just a blot on the inkpad - a piece of paper to be torn up and thrown away - a bump in the line of progress... and I’m not a brave man.

Such accounts convey a sense of those in the public spotlight being menaced by those forces that are opposed to their work; notably, however, such forces do not seem to have been powerful enough to prevent the hero from continuing – rather, they appeared to provide a locus for determination and persistence. While Bennett may not have seen himself as brave man, in this case he was not alone in combating those opposed to the expensive clean-up of Santa Monica Bay –
ultimately, what started as a one-man campaign would come to involve hundreds of community activists, many of whom were inspired by his passionate arguments in favour of a cleaner environment (Sharpsteen, 2010).

Nevertheless, such reports of either hate mail or deadly threats were in the minority amongst the accounts given at interview. Far more frequently cited were examples of audiences reaching out to express positive sentiments such as gratitude, respect and admiration, including many reported instances of people saying ‘thank you’. One notable example came from Tim Flannery who despite being persistently criticised by some of his peers, as discussed in the following chapter, observed that the public correspondence he received was largely positive:

People who write me letters, I’m definitely very flattered because most of them are nice. ‘Thank you for championing a particular cause’, or sometimes ‘thank you for a lovely book’, that sort of stuff...it’s across the board from young people to quite old people... and the responses are generally positive.

Based on the accounts given at interview, the majority of audiences enjoy both the information on offer and the manner in which it is delivered. Conflict clearly does arise, but seems focused on whether the information should be delivered at all, and what it suggests about the values and expertise of the speaker. And certainly, audiences express a sense of the value they see in the individual’s communication – as the accounts show, gratitude, enjoyment, empowerment and inspiration are all outcomes apparent in the correspondence reported.

5.4 Impacts of engagement

Many of those receiving high volumes of correspondence made concerted efforts to respond, in most cases feeling both a sense of obligation to reply and a sense of enjoyment in making a connection. For some, the challenge was in distinguishing
between those whose contact signified a real need for information or interaction and those whose engagement was only superficial. As David Attenborough put it:

People think they know you, in a way in which it is not the case... they think you're a pal, their uncle, or whatever. So they quite like to contact you, just because they know you.

Other participants felt that some interactions they experienced were more akin to expressions of friendship, such as the letters Johnny Ball reported receiving in response to him telling “little stories” on the BBC. Amongst his correspondents were many retired engineers who responded in kind with their own “stories about the war”. This sense of conversations unfolding was also apparent in several other accounts, such as that of the science writer Mathew Ridley who recalled of his reactions to a good book he was reading:

I’m reading a very good book at the moment called Vermeer’s Hat and suddenly I saw something and I thought that has to be wrong; he says that St Helena is 200 kilometres from the coast of Africa, it must be more than that, so I think he probably means 2000, that might be wrong ... and I was thinking maybe I should write to him and then I thought, why would he want to hear from me? And then I thought it’s weird, when you’re reading a book you genuinely feel you’re in a conversation with the author... You feel you know them and you feel they’re already a bit of a mate by the time you’re half way through and that’s actually rather wonderful and so there’s a certain familiarity that readers bring... you know, almost a sort of ‘we were talking about this last night, weren’t we and this is what I’ve got to say on it now’.

Such accounts suggested that for at least some members of an audience, the sense of having a mutual interest, shared experience or common concern is a motivational force for getting in touch.

For others, there was a sense of audiences reaching out, to gain insight or access to the knowledge the science hero held, to become closer to them, or both. At
interview, the author Simon Singh surmised that one of the reasons people approached him was because “you’re coming from a world that they want to belong to” and indeed, elsewhere within the study there was some evidence that this might be the case. For example Helen Caldicott, the anti-nuclear campaigner, reported receiving many offers from people wanting to come and help or offering their services to her. Sometimes, offers of help were startlingly concrete – for example, Nancy Rothwell reported receiving handwritten letters from elderly people, sometimes enclosing £5 ‘to go towards the research’. As she observed:

I’d say that most of them are interested in the science that we do and what we do. Because the sort of diseases we work on are quite common

In some cases, what started as a simple reply to a simple question evolved into an ongoing correspondence, with some having long-running interactions with particular individuals. It was clear that such efforts to engage could have profound effects on the recipient; for example, as Nancy Rothwell recalled:

After the Christmas lectures I got well over 1000 letters and emails. Some of the people who wrote to me still stay in contact. So there was an eight year old who didn't know about going to university, didn't know about any of this, and he kept writing to me. He eventually got a summer job at a London hospital. Anyway, he's nearly finished medicine now.

Rothwell’s account suggests that her young correspondent was actively seeking to engage with what she had to offer, and that through this relationship she had helped to create a sense of direction in the possible future path for this young man. Further evidence of such an impact came from the account of Chris Lintott, previously discussed in Chapter 4, who recalled the significance of corresponding with the astronomer, Patrick Moore. Lintott strongly felt that being acknowledged and encouraged by the ‘star man from the television’ had reinforced his ambition to become an astronomer. Indeed, the interviews produced much anecdotal evidence that Moore had consistently written back to people who contacted him after watching The Sky at Night. By his own account,
with over 2 million viewers per episode, Moore had written hundreds of thousands of letters in response. As he explained:

I have tremendous numbers of letters and... it seems so rude if you don't, so I always do answer them. And I have many questioners, again who I try to answer. That's my role if I've got one... I've got my observatory here and many people come down and use that, they cut their teeth on it so to speak...I talk to them, show them what to do and they go ahead and do it... The only reason people know me at all is that because for the last 50 years I've been putting my head on television...it's part of life, and I always carry cards for when kids come up to me; I never turn any one down.

Moore was credited by several other participants for inspiring a generation of scientists, and one particular insight into Moore's intergenerational reach came from the science broadcaster Quentin Cooper, who recalled asking a large group of science teachers if they had written to Patrick Moore and received a reply; as he recalled “in a room of about 200 people, 70 or 80 put their hands up!”

Such accounts are supported by other sources of evidence suggesting that the simple act of responding to correspondence can have a significant positive impact on young people. Whilst few in this study retained their original correspondence, one very pertinent account has been usefully documented online by the chemist and IgNobel prize winner, Len Fisher, who described an experience of interacting with a member of his audience via correspondence. Following his widely-publicised, IgNobel Award-winning research into how long it takes for biscuits to disintegrate when dipped in a cup of tea, Fisher reported receiving a detailed letter from a 12 year-old schoolboy, which read:

I looked at your formula but don't think you take in the fact that the thickness of the biscuits can affect the result. I have a couple of questions for you. What exactly is L – is it how long you hold the biscuit in for? D and t are they constant? D – is the size/diameter of the holes vary and can change. T – would this be variable depending on the density of the biscuit.
Please send me some biscuits for noticing this.

Fisher reported replying that all the biscuits had run out, thanking the young boy for his comments and wishing him well at school. He then recalled: “Some twelve years later, the same schoolboy, now qualified as a doctor, wrote to me to say that my reply to his letter, taking him seriously, had been the major factor in stimulating him to take up science.” (Fisher, 2015)

Like Fisher, many participants in the study reported hearing from people who had previously encountered them on television, in the lecture hall or in the classroom, saying what an important, inspirational role they had played in their career choices. As Jocelyn Bell Burnell commented:

> It happens more often verbally than in writing, I go somewhere to lecture and a now not-so-young woman in the audience will say ‘because of you I’ve been doing physics’. It makes me feel a bit responsible. And I know one or two kids, girls, who've been called Jocelyn after me and I feel awfully responsible for them! ...Somehow, having a school laboratory named after you is one thing. Having somebody named after you is a totally different ballpark. And that's a totally new experience for me, and I find it a bit startling. And to have other major effects on people’s careers, yes, it does feel a bit responsible.

Such accounts suggest that whilst much correspondence is a simple one-way form of communication, which positions the science hero as a source of superior information, expertise or advice relative to the writer, deeper two-way forms of communication are also present, which appear more closely oriented towards modelling and expressions of inspiration that could be regarded as an invitation for further engagement. There is a sense that, for some, the quest for information belies a deeper need for knowledge or for purpose. Curiosity, as embodied in the asker’s questions, is not always merely satisfied but is stoked. And superficial relationships that may form first through exposure to public talks or media appearances may lead to longer-term effects, such as greater engagement both with the subject material and also the inspiring individual who provides it. In
some cases, that individual becomes a powerful influencer in another person’s life.

Perhaps the most compelling evidence for this effect came following a telephone interview with the ethnobotanist, Mark Plotkin, when an appointment was also made with his assistant Ian Starr, to further discuss Plotkin’s relationship with his audiences. Starr revealed that he had first been attracted to join Plotkin’s organisation after reading about him and perceiving similarities between their worldviews, ideals and practical solutions to the problem of preserving indigenous knowledge in the Amazon. This sense of connection had led him to get in touch, and ultimately to become part of Plotkin’s lineage. As he said of his boss:

I think there's a certain energy about Mark – it's kind of one of these qualitative things, where when Mark speaks, people listen. There's just a lot of confidence in him and respect in what he's done, there's just this X factor. And I don't know what to attribute it to but it’s just a part of Mark's personality that when he talks he's engaging and he's good at bringing down the issues in a way that laypeople can understand, so in that respect he becomes very personable and things become very accessible and I think it's pretty inspiring for people. It really is person-based, just some kind of special attribute, that they're able to and willing to connect with people. Mark is very much a people person and he also happens to be an authority on a lot of issues to do with the Amazon. And those two things make him a pretty formidable communicator about this issue.

Starr’s account characterises Plotkin as being highly personable and charismatic as well as authoritative and knowledgeable. Furthermore, it suggests that he is able to combine these characteristics to communicate in ways that are very appealing for his audiences. Importantly, it also suggests that the audience may come seeking particular knowledge and experiences from their interactions with him. These ideas are important within the context of this study, as they cut to the
heart of how science heroes interact with, affect and in turn are affected by their audiences.

5.5 Relating to the audience

As previously discussed, audiences were clearly interested in engaging with science heroes, as evidenced by the volumes of correspondence received and the attendance of audiences at all manner of public appearances reported by participants. In some cases, a sense of the varied interests of audiences was apparent in the accounts given of what happened when individuals ‘met the audience’, which intersected with but in many cases also differed from the interests of the scientist. As the astrophysicist, Chris Lintott observed of his Sky at Night audiences:

There's a whole set of questions the public are interested in, which may or may not overlap with the questions that scientists are interested in. So if you're communicating, you need to make sure that you're talking in the space where those overlap... I think they're interested in more than we usually give them credit for. I think there's the sense that you talk to the public about black holes, about the Big Bang, and if you're lucky you talk about aliens, and that's the bits of astronomy that they're interested in. But from the feedback we get, they just like the idea that there are telescopes and people using them and that we're trying to explore space, so if what we're exploring this month is a set of galaxies or galaxy formation, then they quite happily invest half an hour of their lives in listening to and learning about galaxy formation, the same way that they - they get almost the same attitude as people who would go to the zoo and ‘I will spend an afternoon sort of learning about the animals that exist in the world’...Like reading travel magazines, I suppose. It’s the kind of ‘what’s out there?’ sense that seems to drive people to come and watch.

Several other participants also expressed an understanding that the needs of their audiences were complex and in some cases, easy to underestimate. As the science
presenter Laura Grant said of her experience trying to find out what her audiences really wanted:

We did five focus groups before we prepared our lecture and basically three-quarters of what we wanted to include went completely out the window. They were just like 'this is so completely boring that it just shouldn't even be in there'. I think that was a really humbling view... that just made that lecture tour so successful compared to other stuff that we've done, where we haven't had or perhaps haven't made time to do as much of that. It just made a massive difference. I think it makes a difference in your own confidence that you know that it's going to be on-the-whole better received. But also that you are talking about things that are relevant to people's lives rather than things that you think we should talk about...You think of your role as presenting. But I think that we need to listen more and potentially talk less.

Grant's account suggests something of a revelation, in realising that her previous ideas of what audiences wanted were quote wrong. In this case, a majority of the content elements that she and her colleagues, being experts, had assumed were both interesting and important were neither – at least, not to this audience. Their response seems unequivocal: on being invited to participate in the creation of content, they rejected most of the experts' ideas and seized the opportunity to demand content that was directly relevant to themselves.

Grant's account also draws direct parallels between listening to the audience and achieving better outcomes as a result, and she was not alone in this view. As John Coggins recalled of his time on the Agricultural and Food Research Council, when council members were expected to “go around explaining what all this public money was being spent on and why we were doing it”:

I used to talk about the problems of generating enough food and the sort of ways you could modify crops...I think what I was always pretty good at doing was to get the audience to participate and have some discussion:
‘Well here are some of the issues, what do you think about it? Can you see advantages, disadvantages, does this have an ethical problem with this?’ Because I think one of the issues in science is it isn’t black and white and the public thinks science is black and white. You have some data at a particular time and you can make the best interpretation you can. Next year you may have better experimental data and you may come to a different conclusion. It’s trying to convey this, that science is dynamic and it’s moving on – but also that it really can at least provide some answers to the challenging questions.

Coggins’ account reveals a desire to engage audiences through participative, open-ended discussions that respond to the differing interests and information needs of the audience. It also reveals a source of tension between the scientist and the audience; that the idea of science having certainty does not quite match its reality, and that scientific ‘facts’ are temporally dependent and continually evolving. Nevertheless, despite its uncertainty, audiences seemingly must grapple with the fact that science is still useful. By highlighting this tension, Coggin shines light on a major difficulty in realizing the utilitarian vision for science communication, which suggests that talking about science will help to build public support for it. From his account, the suggestion seems to be the opposite: that talking about the science makes people less accepting of its recommendations. Indeed, Coggin’s account suggests that many people find the messiness, uncertainty and dynamic nature of the science behind genetically modified organisms hard to accept; parsing risk, the human mind craves information that is not only what it wants to hear, but can be relied on.

This sense of audiences wanting to be able to rely on the information – or to have certainty and therefore confidence in it – was conveyed several times at interview. As Anne Henderson-Sellers said of the consequences for scientists not appearing to be certain:

If you hear someone who isn't quite sure, bumbles a little bit, it can taint the whole field in fact, and not just with that scientist's work but everyone
else's...I could give you a million examples, but I suppose the most classic has been climate change – and I'm not being disrespectful to colleagues who work in that field, I mean Jim Hansen for instance in NASA, is an absolutely fantastic scientist and an absolutely delightful, committed, passionate, wonderful person. But in terms of engaging with an audience to convince them of his arguments and bring them with him, that's not a skillset he has. Whenever there's been a big hurricane or something scientists can be asked, is this due to climate change? Well what they all do is say, 'well I suppose...' and they would read the science: 'Well statistically one can only model this but that's the sort of pattern we would see.' Whereas actually that's not what the public are used to. The public are used to hearing someone saying, ‘I believe it is...’ Because they don't want you to start going into relative risks and likelihoods or those sorts of things. I think the inability to passionately communicate science is detrimental to that science.

Again, this account conveys the value of a ‘passionate’ communicator in reassuring and engaging public audiences, who is able to draw not just on the messy, indefinite facts but use rhetorical skills to successfully argue the case.

Occasionally, participants were able to describe how their internal perceptions of themselves differed from those of their audiences. One very detailed example came from the account of DNA pioneer, Alec Jeffries, who felt that in the process of becoming famous an alternate version of himself had also begun to emerge in the public domain – a larger, more accomplished, more stylized version of himself that bore little resemblance to reality. Over time, he felt that the ‘real’ Alec Jeffries would most likely be forgotten in favour of the ‘giant’. As he mused:

Having people trembling in my presence - argh, I hate it... I will use the words of a teacher I met two weeks ago, when I gave an A-level revision talk down in London... A couple of them came afterwards and said, ‘wow that was absolutely fantastic. We've met a legend’. So I've now apparently
been turned into a legend. Now that’s none of my doing. But obviously I’ve got a name out there...

There’s the real me that I know, my family love and hate and all the rest of it - just the ordinary bloke. Then you’ve got this legendary figure out there who now seems to be developing attributes quite separate from my own. So there are two me’s charging around. There’s a mythical monster and there’s the real me and they’re becoming less and less congruent with each other. That’s a most peculiar position to be in.

The mythical me is tremendously ancient. In fact we had some school children visiting the department recently and they were told about DNA fingerprinting and someone said, ‘oh that happened so long ago, that he’s dead’. It was a bit of a statement. So mythical me is tall, distinguished, terribly well dressed - a rather splendid figure in every possible sense. Mythical me is incredibly intelligent in every conceivable matter that could possibly be discussed, enormously learned and erudite and someone in whose presence you should be in fear and trembling - quite rightly! That’s the mythical me.

The real me is this sort of shambling scruff that has a lot of fun in what he does, loses his temper and gets exasperated just like any other human being. But the real me just seems to have got born with a lucky streak – always been very lucky in science – right place, right time, right idea. So the mythical me and the real me are just so remotely different. I see it over and over again. You may have - a judge or someone like that may come and visit me and they clearly walk through the door expecting to see the mythical me and then meet the real me. You see them doing a double-take, looking me up and down, looking around my bombsite of an office and thinking, ‘no that can’t be him. Someone’s made a mistake here’. So it is very strange. He just doesn’t exist. It’s a complete fiction.

Jeffries’ account reveals something quite fundamental about the experience of being a science hero – that it is a transformational process, over which the heroes
themselves may wield only limited control. Whilst public image can be influenced to a certain extent, for example by ‘seizing control’ of media interviews or designing communication experiences to create a particular type of impression, ultimately the role of hero is situated firmly in the eyes of the beholder.

The needs, demands and desires of the audience are also evident to those who make the effort to listen to and engage with them, and from time to time their communication approaches also give rise to heroic personae; for, as the preceding accounts show, gratitude flows to those whose knowledge is shown to be game-changing, life-saving, critical to the future of the planet, bringing better health, prosperity or fortune. It was also clear that whilst media portrayals of science undoubtedly contributed to this effect, heroes themselves also did so.

Such accounts add another dimension to the behaviour of audiences, which as earlier discussed can be characterised as information-seeking and relational. In addition, it appears they may also seek to be engaged with critical issues (as in the case of Coggins’ audiences), entertained in their valuable recreational time (as in the case of Lintott’s), respected with content that is relevant and interesting (as in the case of Grant’s) and excited by inspirational personae and ideas (as in the case of Jeffrey’s). In short, one can see audiences as discerning and engaged, bringing their own agendas and ideas to the interaction and perceiving science-related communication as both a source of information and a form of entertainment.

This being the case, it came as no surprise to learn that the media industry has identified Science and Factual (or in the United Kingdom, ‘Specialist Factual’) as a specific category of entertainment media programming (WCSFP, 2015). Further insight into the workings of this sector came from a former content producer for the BBC, Paul Manners, who reflected on how Rough Science had deliberately focused on profiling highly personable individuals:
There were certain things we had in mind about what puts people off science, we felt that very dry and dull communicators wouldn’t work, we wanted people who were really good at talking about science, who were excited about science, who didn’t fit the kind of stereotypical image of the scientist, ‘cause we wanted people to feel that scientists are not this stereotype of either completely eccentric wild-haired professors or just dull technocratic people, so we looked for people who had a real warmth and a real human quality to them. And we loved their science but we were really focused on them as convincing human beings! The kind of person that if you sat down in a pub, you’d like to talk to. And so we selected people like Jonathan Hare who had all those qualities: brilliant scientist, great to talk about his science but just a completely magical personality that just draws you in, and people like Mike Bullivant from the OU, who’s a chemist but just funny, witty, dry, good with people. So it was those human qualities that we foregrounded, but obviously sitting beneath it we wanted to cover the range of scientific skills that would help you in a difficult situation. So we were looking for natural science skills in botany, marine biology but also engineering and physics and trying to cover all the disciplines, personified in people you’d have fun with in social situations.

Manner’s view from the world of television, which has a clear focus on the personalities and communication skills of its presenters contrasts with a view from the world of radio, in which the broadcaster Quentin Cooper, said:

One of the things I like about the program I do is that we don't just go out there and find the brilliant communicators...explaining it on behalf of the people who've done the work.... we'll go and find the people who've done the work and we'll go and talk directly to them. Quite a lot of the time I’m talking to people, it might be the first interview they’ve done that year, and sometimes you’re talking to somebody who’s been working in the field for thirty years and they’re going 'this is the first interview I’ve ever done'. Now I love that ability to mine all that knowledge that nobody's ever gone to before and it’s the reverse of the celebrity world...you can talk to these
scientists that have been working in this planet-changing work for 30 years and nobody’s bothered to talk to them. What a privilege! To be able to go and grab these people. They will be, sometimes, a bit nervous and it’s my job to reassure them that we’re not going to take them away from their area...my job is also when they drift into jargon, or whatever, to nudge them back but at the same time, without - I hope - making it so the listener is left out of it. If I start to become too much like the scientists then you’ve got a group of scientists around the table - and the audience is at home going 'er, I’m sure they're having a great time but I’ve really lost track of what’s going on’. I’m - hopefully - the bridge between the audience and the people in the conversation, without the people in the conversation feeling like they've been slowed down or stopped or misunderstood.

A sense of being ‘the bridge’ between science and society similarly came through in an account from the presenter Adam Hart Davis, who observed:

What I am good at is taking other people’s ideas and stapling them together, and then I’m very articulate with words and writing them in the right order... and that’s, in the end, my trick. To make people think they understand and so on. I once did a piece about the Stirling engine. Robert Stirling and his engine, and it was quite good fun... and I had a lovely letter from an engineer who said 'I’ve always wondered how the Stirling engine worked, and they taught me in third year and I never understood and what you said was brilliant. Could you send me a transcript?’ And I wrote back and said ‘oh, we don’t have one’ and I thought ‘hang on a second, I could watch the tape, and I could write it down’. And I watched it and what I said was 'well, you see the heat goes in here and this goes round', and it was complete gibberish. It didn't mean anything at all, but it was the interaction of me and the machine and nonsense words that made it seem to be sensible, and seemed to make him think he had understood. And that’s what I like, I get away with murder. People say all I do is testiculate, all I do is wave my arms around talking bollocks.
In these accounts, these different members of the media depict their role as translators for science, facilitating the transformation of information into forms that are person-centred and easy to understand. In the medium of reality television, which is relatively unmediated, Manners suggests that the use of highly personable scientists is essential to conveying a sense of story. In the medium of radio, Cooper draws attention to the importance of the facilitated conversation, highlighting the delights of in-depth discussion and the challenges of avoiding jargon to draw out the importance of the work so that the listener stays involved. Hart-Davis draws attention to the combination of language, visuals and storytelling structure that he feels enables learning to take place, despite the absence of technical terminology. And it is to the question of how ideas about science are mediated by the communicator that the discussion now turns.

5.6 Science heroes and the representations of science

Different characterizations of science were apparent within the accounts participants gave of their communication experiences, which could be categorized into three distinctly different ideas or representations of what science is, specifically:

- Science as a process of enquiry that creates a reliable and comprehensive knowledge base to explain the world;

- Science as fascinating, exciting, dramatic and stimulating; and

- Science as a social undertaking, with benefits for society.

Science as a process of enquiry that ultimately creates a reliable and comprehensive knowledge base to explain the world;

This view of science was relatively common, situating the communicator as an expert with access to a reliable and robust body of knowledge, against which the
uncertainty of current problems, problem-solving processes and possible solutions is situated. Central to this idea is the communicator as a guide to or broker of expert knowledge, which on the one hand appears to be finite, certain and concrete, and therefore trustworthy, and on the other appears to be infinite, uncertain and constantly changing, and therefore untrustworthy. In the midst of such apparent contradiction, the communicator appears to be a knowledgeable intermediary, able to represent knowledge from and provide insights into a complex, limitless and intimidating scientific realm.

This characterization was particularly apparent in the communication accounts of research scientists, many of whom spoke of the need for accurate information to be made available in the public domain, in order to help inform and improve public decision-making. Some felt that communicating effectively could help improve social understandings of scientific evidence and the actual risks posed by new technologies or global climate change; in one example, the microbiologist Nancy Millis described her motivations as follows:

Something I believe in strongly is that we ought to make our decisions based on the best possible science reasoning... you have to respond to those ‘probably’ scenarios and as a scientist I feel I should make that point clear and loudly wherever possible, and so I do. I feel simply that as a scientist, it’s your duty to...I think it’s a serious matter, that we shouldn’t allow shoddy statements to become accepted as the policy-making statements, which you find yourself living under because they have been made on false premises.

Others highlighted the importance of playing ‘the long game’ when it came to sharing information with the media, in order to maintain credibility for the future. For example, as the physician and developer of the cochlear implant, Graeme Clark recalled:

Early on in the new era of cochlear research I was involved in the first mini telethon in 1973. In some ways it was breaking new ground for
communications with scientists. We tried to be conservative, cautious – I always went to press with something up my sleeve and tried to never make a statement unsupported by initial data. Some colleagues said later over the dinner table that I was being over-secretive, but I didn’t want to tell people and give them false information. I hope we create a culture and a climate where if anyone proves us wrong, it’s us. So we need to do the work thoroughly and double check it’s been done properly... this attitude proved to be very valuable when we came to commercialise the cochlear implant – our research was believable. Others were doing non-rigorous clinical studies and making claims not thoroughly backed up. But with cochlear, everybody believed what we said. We were careful, we were accurate and we only went to press when we were ready.

Clark’s comments suggest a strong preference for caution when communicating about his potentially life-changing research, in order to both avoid disappointing potential end users and to preserve the credibility of any future announcements that might arise from the work. From his account, one gains a sense that he had quiet confidence in the work, based on a solid body of rigorous research – in addition, there is an awareness of the end goal: to bring a transformative technology to market with a high degree of confidence. Clark, like many others at interview, saw both philosophical and commercial dangers in speaking out too soon and potentially undermining a longer term objective.

Whilst Clark highlighted the need to wait for certainty, others spoke about the difficulties of communicating clearly when science is inherently uncertain. As the climate scientist, Courtney Schumacher observed:

Scientists are - most of us are pretty shy about saying something, unless we're pretty darn sure...So there’s now a kind of weight of evidence that’s accumulated where scientists are more willing to speak publicly about things to the general public, to the press, to the government agencies, to Congress about this... I really enjoy having conversations with skeptics about climate change and...why we know there’s a large human fingerprint
on changes and temperature and rain patterns and things like that. But there's also natural variability and we still, as scientists, are uncertain.

One approach to dealing with this uncertainty was to stick closely to the facts, and communicate only the information that was supported by solid evidence. As Fiona Stanley observed of her appearance in a TV advertisement:

I actually went on television to stop women smoking. And there I was in a white coat saying 'there are statistics that are very frightening...lung cancer rates are going up dramatically due to smoking'. And it switched over to a woman dying on a respirator with her family gathered around her and then coming back to me saying 'give up now, before it's too late.' It got 98% penetration over the whole of WA and I was a public face... (but) I didn't get any criticism from anyone in my profession about that...

Stanley's account suggested that by sticking to the facts she was able to avoid negative repercussions from her colleagues, which might have otherwise arisen. Others also suggested that the process of communication brought considerable risks if not done 'in the right way'. The primary considerations appeared to be the possible damage done to both the reputation of science and to one's own scientific credibility by straying beyond the available evidence base. As one participant observed of another high profile communicator:

...I think X overstepped it, and went beyond the data, and I think lost credibility. I think that's a very important lesson for us, that those of us who have high profiles and do have something to say...in terms of the important outcomes for the future of the country... We have to make sure that we're very clear about the data and what the evidence is showing.

Others also felt that a balance was needed between telling the inspiring stories of science and sticking to the facts. For example, as Sylvia O Earle said:

The real stories are the wonderful parts of science. But scientists use a language that only scientists understand and I have become convinced
over the years that it is important to communicate in that way to your fellow scientists, but vital also to convey what we discover to the public and if we fail to do so, we fail as scientists. We have to allow the rest of the world in on the new discoveries. It is important for decision-making, our future. It’s vital in fact. And you must NOT exaggerate. If you do that should incur the scorn of your colleagues. Do everything you can to get the story straight. If you speculate, say you are speculating. Don’t for example suggest that sharks are man eaters. They are not. Peter Benchley with “Jaws” never intended that people believe for example that sharks are dangerous. He was just telling a good story and it was a blow to him that people took that as the truth. Sharks are not like that. Many people justify killing sharks because they think that was a true story.

From such accounts, it was apparent that there were some tensions around communication of science, including the need to be passionate and tell stories that explain, the need to speak only of what is fact and with support from an evidence base, but also to convey both confidence and uncertainty. These tensions were perhaps best summarized by the science festival director, Simon Gage, who said:

"Behind the scenes there is a tension between these. Some people tell me that those that do go and speak are barely qualified, others in the scientific community of vulgarising or debasing the subject...(but) it’s not implicit that if you’re talking to the public you have to do it with bad science - you do it with good communication...Pretty much at every level of science, it's an approximation, of a more complicated story. You get taught it in a simplistic form as you got through your education, and you get more accurate and more complicated forms as you go along...it's implicit in the whole process of communicating science, that you are providing approximate descriptions of the world in almost every instance. The exception to that is when you’re right at the sharp end of scientific research, when you don’t."
Gage's comments suggest that good communication contains a level of detail that is appropriate to the audience, and that absolute accuracy is not fixed; rather it scales with the audience's need for explicit scientific and technical information to be shared, and that the need for highly detailed, non-generalised and scientifically accurate information is really restricted to those already 'in the know'. Similarly, Julia Higgins distinguished between differing audiences for science, arguing that communication underpins much of scientific practice:

It seems to me that the whole of research is about communicating but it depends to whom you're talking. Because you start by needing to communicate to your team. Then you have to communicate to other scientists. To publish the stuff you have to be able to talk about it and you have to be able to talk in ways that they understand it. That's the specialists. Then you often find you're talking to other scientists in more general scientific terms. Then there's the general public which might include anything from politicians at one end, to school kids at the other. All of those require a different way of communicating, but only in the sense that you have to simplify more and more.

Such views are supported by those of policy-makers such as the UK's former Minister for Science, Ian Taylor, who observed that while scientists are often focused on communicating the detail, conveying the big picture is more critical to those responsible for decision-making in the public domain. As he said:

Scientists tend to get too wrapped up in what they do...if you think about it, as science minister I was responsible for big physics, heavy physics - and initiating British funding of the large hadron collider, I had to know what that was doing...that doesn't mean to say I had to do the physics...at the other end of the scientific spectrum, for example I was responsible for the progressive funding of the unravelling of the human genome...it was my decision to fund the research that led to the cloning of Dolly the Sheep for example, and I had to explain that to the public, as to why we had done that. And in the middle you get all kinds of exciting stuff about new metals
and catalysis and all these crash together. So if you're in the political world, like me, I don't need to be a physicist to describe physics and I can't both be a physicist with biotechnologist at the other end...but I have to talk about them in as animated a form as I can, when the matter is before us and the subject is being discussed and understand the relative significance...and the relative priorities that I might have to give to difficult funding rounds. And I was also space minister, responsible for the whole of the civil and defence space funding...

Taylor’s account suggests that processes of translation and explanation underpin how public policy-makers, who must speak for the whole of science, represent it in the political and public domains. This perspective suggests that a supportive minister must have access to clear, succinct and relatable depictions of science, both for the sake of their own understanding and in order to contribute this information as compellingly as possible into a debate-driven, democratic decision-making process. It also suggests that not all science can ‘win’; rather, it must compete with many other priorities for visibility, funding and public support. Clearly, determining what is in the public good requires a constant process of appraisal; of relative significance, value and future returns.

Presumably, in this mix is an assessment of how the science ‘looks’ to the public; being voter-oriented, politicians are naturally sensitive to a whole spectrum of possible issues arising from their policy and funding decisions, and the issue of whether the science is accurate is just one of them. One compelling example of this came from the environmental scientist Anne Henderson-Sellers, who discussed the difficulties of balancing ‘accurate’ messages about science – which was often described as an inherently uncertain, messy, equivocal and fluid practice –with clear and consistent messages that could be acted upon by policy-makers. As she described of the consensus communication that followed the COP15 climate negotiations:

I’ve just come back from the climate conference in Copenhagen where the message is still the message. The message is 'the planet is warming, the
signal is unequivocal, now it's going faster than we thought it was going
to, which means that now we're in a more serious situation than we
thought, which means that action, which was already very urgent is now
dramatically desperately urgent'. And so how do you keep saying that
without a) sounding like you're just repeating yourself? Because of course
you are just repeating yourself as a scientific group and b) also trying to
deliver a message that offers politicians a route forward. It's no good
saying, even if you think it and some of us do, that we're already past
crucial tipping points, because if you say that, then what can a politician
do? If we're already totally bugged what's the point of taking any action?
So you don't want to make that the only route that's available. And also,
you want to make it clear. In fact the Danish prime minister, a remarkable
man, came along to the closing session, as such people do. But
interestingly interacted with some of the scientists there ...the sense from
the scientists was 'look, what was said in IPCC 4th assessment report?
Now it's more desperate'. And he was actually very clear, he said 'don't
give me a moving target'... At one point some of the scientists were saying
'look 2 degrees was never a number that we had a scientific basis for; if you
wanted a number, well then, no more than 2 degrees'. And then ...'well
maybe we should be pitching lower than that'... And he said 'don't do this.
Because I believe you, and even if you're right we can't negotiate like this.
This is already hard. Don't now tell me that this isn't the right number.
Because I don't even know if I can get 180 nations together on that
number. You make it a different number and it will probably just fall apart
because the target has changed'. It was interesting, I sort of knew it but it
was interesting to actually hear an articulate national leader say, not 'I
don't care' but 'you're making my job too hard by changing the science
now'.

Henderson-Sellers’ account is fascinating in that it reveals some of the difficulty
politicians experience in utilizing scientific information, in which accuracy can be
something of a moveable feast, to underpin public policy. In this case, as
scientific approximations became more detailed, scientists saw that the potential
risks had become greater and wanted to see the latest figures reflected in emerging policy. To the policy-maker, however, the accuracy of the science at this point was not the crucial element – rather, it was the consistency of the message needed to attain consensus in a long running, delicate and difficult global climate negotiation.

From such accounts it’s clear that great complexities exist within the processes of communicating, translating and ultimately utilizing science in the public domain and that some scientists, focused on accuracy in the detail, may lack an understanding of how the knowledge they generate may not be ‘right’ despite its accuracy. As Roland Jackson observed:

Some people in the science community will quote GM as an example of how things went wrong, i.e. the view of a certain group of scientists to some degree were rejected by the public; there's still an element of that around. For some, events like that have been drivers. But people are starting to think more subtly than that now. There's still a group of scientists who aren't ashamed of taking a scientistic view of the world, still; they're implicitly saying that everybody else ought to share their thoroughly science-based values - isn't it obvious? I think they're a relatively small number, but they do include some influential people. It’s the sort of sense that science has the answers over and above everything else, that it can and will in the future have the answers. It’s the belief in the scientific and technological fix, and a sense that if something is scientifically possible, it’s an advance and by definition it must be right to do.

That broad swathes of society do not always accept that the advances brought about through science are entirely positive is very well documented. Analyses show that public controversy over the introduction of almost any new technology, including genetically modified food, fracking and vaccines is very widespread, and that many factors play into this. For many scientists, the need to express what’s correct scientifically must be balanced against the desire to say
what’s right from a personal perspective. The marine biologist, Usha Varanasi succinctly summarised this problem as follows:

I may be able to use my personal judgement and say 3000 is better than 7000. I mean 2000 to 8000 is my numbers, but I may say 3000 is better because you would save the species...but I shouldn't say 3000 is better, because somebody else needs to make that decision, what is better for society. Society needs to make this decision. What happens to scientists is sometimes media can make them say what is good for society. I feel like if I'm not an expert about what's good for society I should not make that statement as a scientist. So the cross or whatever the burden that scientists bear is we are also human beings. We also have personal opinions. But our personal opinions when we wear the scientist hat are taken as fact. So if I need to make a personal statement that I would rather you take only 3000 fish out of the water, I have to absolutely say: this is not bounded by fact. That is a mistake we make quite often because we do feel we’re to be considered wise and all knowing, and the media are coming to us.

Whilst it was apparent at interview that many people were similarly conscious – and cautious – of overstepping the bounds of fact, several participants hinted that they enjoyed the opportunity that having a media profile gave them to ‘make a difference’. As the Nobel laureate, Harry Kroto explained, of his motivations to talk publicly about bigger issues than his research in molecular chemistry:

C60 is important, and of course it’s pretty and I do love it...but after 23 years, nearly quarter of a century it’s almost like a ball and chain around my feet, because it’s led to a lot of things I feel very strongly about and, through the Nobel Prize, has given me some mechanism for doing these things in a way that I feel responsible to follow up. And had they not done it, I would not be able to do that, and so would have had an easier life. I don't think it's all good; it's nothing like what people think it is. Of course it depends on the individual, they can just say 'no I'm just going to carry
on, the way I did before.’ I don’t feel that way, there are things I feel very concerned about and I am in a position to do something... you’re out on some sort of pedestal. But that pedestal disappears as soon as you talk.

Kroto’s account reveals a very important aspect of success as a science hero, which is that in gaining a reputation as an expert, new opportunities arise to talk about matters about which one feels passionate. Despite not perhaps being a recognised expert in these broader domains, there appear to be significant benefits in contributing to broader narratives about science, such as achieving outcomes for causes about which one feels passionate. For example, as the physician and former Australian of the Year, Ian Frazer said of gaining influence over important policy outcomes:

Suddenly you become an instant expert on everything, at least in the public and perhaps to some extent in the media’s eye, so that they phone you up and ask you for a comment on things. One of the areas that I got involved with during the year that I was Australian of the Year was the plan to sell off the Snowy River Scheme. I was one of the 50 signatories to the letter that appeared in The Australian about that, which created quite a bit of interest and controversy from the media and, also interestingly enough, from the Prime Minister who phoned me up to ask me whether I’d been persuaded to sign the letter. I said, ‘no, I did it because I chose to’ - because they were sounding out what they were going to do about it and they obviously decided they’d phone as many of the people who signed the letter as they could and just see what the public opinion was about the thing. The net result of course was the Federal Government reversed its decision, which then forced the New South Wales Government to reverse theirs. So it does actually work. You get this public profile and then the public profile influences things.

Such accounts suggest an interesting evolution in the professional life of those who represent science in the public domain; whilst initially communicating just within their own spheres of expertise, pressures and opportunities to do more also rapidly arise. From being a specialist, one may easily ‘branch out’ to become
a generalist, able to commentate on a much wider range of subject material - not confined only to speaking about the facts, which as previous examples show are often evolving and complex, and therefore difficult to communicate succinctly, but able to talk about the significance of the science and what it might mean for people. As Simon Gage observed of this evolution:

You start with the common occurrence of the scientist appearing on the news, not really being very convincing, hamstrung by their reluctance to be as clear cut as most of the other people...(there are) a few image issues...the scientific community wasn't ready 20 years ago to go on pedestals. In fact some people reacted rather adversely to it; this was counter to what they got into science for. But as time has gone by I think they've got it. They realise you don't want to put someone on a platform to represent your institution, that's so boring to people.

Gage's observation is that whilst most scientists see accuracy as very important, that same accuracy is also seen as boring from the audience perspective, putting scientists at a disadvantage when communicating in the public sphere. Indeed, as Paul Manners' earlier account suggested, characteristics selected for by broadcasters when recruiting scientists to their television programs are not related to the detail of their science, but to their ability to make it interesting and human-centred. And many such individuals utilize a distinctly different characterization of science in order to make their communication about it more interesting.

**Science as fascinating, exciting, dramatic and stimulating.**

In characterizing science as a dynamic and exciting process of obtaining knowledge, individuals often appear to situate themselves as an investigator with the power to reveal the truth behind profound and important phenomena. This characterization was particularly apparent in the communication accounts of those with a broadcast media history and those with a strong teaching focus, who often expressed a desire to ‘reach out’, inspire and excite people.
Detectable within this idea is the explorer archetype, of individuals making exciting discoveries and bringing them to the attention of the world. And, like adventurers returning from new frontiers, many of the science heroes recounted stories of the stories that they told. In one pertinent example, the biologist Nancy Rothwell said of her approach:

I communicate by telling stories, about discovering things and a little bit of finding the unknown and things...I’m always thinking about, oh that would be a good story to put in. A colleague of mine got a picture of a guy with a huge nail in his head on an x-ray. I thought, what a fantastic thing to tell a story about. You just see them, wherever they crop up.

Rothwell’s account suggests that she collects stories to tell, and this appeared to be a common practice for many participants in the study. Similarly, Usha Varanasi put it:

I always like to give a story. I feel that a scientist is both a detective – a sleuth – and a storyteller...you can show how that connects, how you put pieces together, then what impact it made. I prepare for things like how and why and what...No matter where, whatever I am presenting the questions are: what was the question? Why was it important? How did I go about addressing the question? What was the impact of the results? If you do that in every part of your work I think people start seeing a story...It sticks with people.

Varanasi’s account suggests that she uses an exploratory structure to craft her communications, clearly laying out the broader vision and purpose for the acquisition of knowledge and situating it in a social context that conveys the significance of the work. In another example, the molecular biologist, Nancy Millis similarly recalled using a systematic approach to communicate the science behind genetic engineering:

When it first began way back in ’75 people really had horrendous pictures in their mind of what’s this technology going to do, monsters and triffids
and you know, just think about it! The understanding of the process was virtually zero... So there was a lot of talking to be done at that time about 'let's try and understand what your concerns are'... we say, 'well please can you tell me what is it you fear may happen?' Then they’ll give you some very vague statement like, 'you will make monstrous organisms or home-grown pathogens which will cause terrible damage either to plants or people or both'. You'll say, 'but can you explain to me how you think this is going to happen?' and of course it’s not a very good answer (that) comes back because the understanding of the process is hopeless or is rudimentary at best. So you’ve got to try and make that as simple as you possibly can but with some sort of... simplified model, which they can sort of relate to and try and explain the point the technology has reached and they haven’t got a new creature by this technology... you go through the whole catechism of questions... what are the hazards? How likely is it that each of those risks will happen? How awful would it be if it did? And can you do anything about alleviating the problem should the worst happen?

Millis’ account suggests that she approaches the communication from a starting point that recognizes and takes her audience’s fears seriously, but works systematically towards creating alternative views of what is both possible and likely. In it there is a sense that she feels responsibility for bringing her audiences accurate information that is contextualized in ways that make meaning for them, with the aim of persuading them towards different views of the technology. And, like Varanasi, she employs a structured approach that enables the audience to understand the ‘story’ of GMO from a different perspective.

Another example of this approach came from the palaeontologist, Mike Archer, who talked about using many different stories to engage his audiences in a field about which he was personally enthusiastic:

I love to get other people to understand why this is exciting. It’s probably the most effective method of communicating. I do this when I teach in first year lectures - doesn’t matter what the topic is - I find things. I will
rewrite the topic until I have deliberately wrapped it around a series of examples about which I am personally enthusiastic or have had communicated to me why other people are enthusiastic about it and can reflect that. To the extent that I can put that into lectures, I will completely engage an audience... I remember somebody saying to me once, when I was in Canberra and I was still in my early twenties - I was just visiting and they were asking me, ‘what’ve you been doing?’ I mentioned that we'd found this fossil deposit and I was enthusing. I just felt excited about it and I was explaining why. There's automatically body animation with it and somebody said to me, it's the first sort of time they put a mirror up in front of me and said, ‘you know, this is so you’. I said, ‘what are you talking about?’ They said 'you know, just listen to the way you're presenting. You're just talking about an old rock with a funny looking old bone sticking out of it and it's like the most exciting thing that's happened this year in the whole world’. I didn’t stop to think about it, but of course, to me it is. The scientific discovery to me is out of context. My interest is totally what it means and what it tells us and what it upsets about something we've previously thought and why everybody should pay attention to this.

Similarly, Adam Savage reflected on how easy it was to tell stories when he felt as if he was discovering something:

There's that naturalness about the telling of the story. When we're really thrilled by something, when we find something that's exciting, it's easy to communicate.

In many of the accounts given at interview, a similarly strong sense of ease when describing a passion for their fields, finding out new information and sharing that with people emerged. For example, as science broadcaster, Kathy Sykes recalled:

In my alternative medicine series, I was on a quest to find stuff out and I was learning... this way of trying to empower people, philosophically I just believe in it much more. So few of us really know everything about
anything, it just feels like the way that I think we should as scientists be presenting things...

Paul Manners described how the demands of television contrast with those of science:

What really works for television is story, narrative, and personality...you want to take people on some kind of journey, adventure, jeopardy that has to be dealt with, some kind of quest. The classic forms of narrative that have been around for thousands of years. That's how we think, in stories. and television is great at presenting people dealing with the consequences of the story that they're part of. And so that is a very different mind set to what many scientists have and many policy makers have, which is 'we have a body of knowledge and we have a set of issues and we need to inform people'. And so you have two different worlds with ways of making sense of what is in it, the same thing.

While such views were quite commonly expressed at interview, several participants had contrasting views, based on what they saw to be a need to engage people emotionally. In some interviews there was a sense of individuals wanting to 'hook' the audience, in order to engage them around a particular view – this was most apparent in those communicating issues of environmental protection and human health. For example, the former science teacher, Howard Bennett who said:

I never considered myself an environmentalist, just a human being...I could always put how I felt into words. I could always say more or less what was in my mind and I was never shy about it... with an environment issue, the more graphic you can get, the more startling, horrific, attention-getting, use whatever words you like. There is no limit, within the bounds of good taste.

Bennett's account suggests that he perceives 'no limits' in the imagery that he can use in order to excite and engage his audiences; indeed, from his perspective the
campaign to ‘save the bay’ was successful, absolutely justifying the means used to achieve an outcome that was ultimately of great benefit to both the Santa Monica community and the bay’s environment.

**Science as a social undertaking, with benefits for society.**

A number of participants discussed characterizing science as a fundamentally positive, beneficial and human-centred practice, in order to counteract negative imagery of science and its consequences. This characterization of science enabled the communicator to convey a sense of the benefits that science brings to the world, and was particularly apparent in the communication accounts of those who spoke of a desire to persuade their audiences to take on alternate views or to trigger some kind of behavioural change.

One of the most important reasons given at interview for humanizing the accounts of science was that wider society has become wary of science on a number of fronts, both for historical reasons and because of the way it is portrayed within the media. Illustrating the former point, John Coggins commented on how major changes in biological sciences, with the advent of genetic engineering, changed the communication demands on his field:

> In the 70s biological science, especially, suddenly was faced with some big ethical problems...most of the debate was about, ‘well we don't know what the consequences will be, perhaps we shouldn’t do it’ but pretty soon people realise they could do it and they got some rather useful results from doing it. So the anti-arguments were kind of washed away and we pressed on – but maybe we pressed on too rapidly because there were some things that we didn’t explore thoroughly. Gradually the public became disillusioned... I mean there were disasters like, in Britain, the BSE disaster...all these unpleasant things were fed back to animals and horrible disease emerged and started to spread around. Although probably it's all sorted out and contained now, this generates a huge amount of public lack of confidence. I understand that the scientists were working to their own
agenda and were not consulting the public so I think that’s been an issue... We need to somehow recapture public confidence and I think part of that is being more honest with the public. Part of it, I think, is that we really have to work hard to make sure that bright, young people realise there are wonderful challenges in science and huge problems to solve and they need to get stuck in.

Illustrating the latter point, that negative media depictions of science place new demands on scientists in terms of communication, the broadcaster Quentin Cooper observed:

Science is always journeying into the unknown, and the unknown is inherently scary. So it’s always easy to scare people about science. That’s why you get Frankenstein food headlines... the flipside of that is you can always say 'we’re five years away from every known disease' or whatever it might be... There’s always something you can fight with people about and we don’t know enough about. So science has the potential to be scary, and scary sells newspapers. Because newspapers’ jobs are not to reflect the world as it is; newspapers’ jobs are to sell newspapers by building up stories. And it’s the same in the sports section - we don’t say 'we have no idea who’s going to be transferred to this team tomorrow'. If you don’t know, you make up a big story! David Beckham to join Luton! You build that up. And science can’t expect - you know people in the world of science expect to be given special treatment. It’s not. It’s treated exactly the same as other things, but it has the potential to scare people.

Such accounts describe public perceptions of science as being ambivalent at best and fearful at worst, with science potentially seen both as working against the greater good of society and as having the capacity to unleash dangerous, risky or unacceptable consequences on to people. To combat such ideas, individuals sometimes used narratives of personal endeavour in order to ‘humanize’ their messages and build an emotional connection or rapport with their audiences. One example came from the mathematician, Michael Atiyah who said:
I try to indicate that mathematics involves human beings...I try to give them, as far as possible, proof in the way I talk about it myself and when I say what other people have done, trying to convey that it’s a human activity. Secondly I try to convey that stages of mathematics are a bit like an artistic creation, where you use not just your subject or reasoning faculty, you also use your imaginative faculties; try to search for the truth in the parts, see what you see, its hidden meaning, looking for the future and guessing what’s going to happen. So I try to convey it as a creative, dynamic process, not just a mechanical process of formal proofs.

Throughout the interviews there was a clear sense that communicating the lived, human experiences of working in the field was important for engaging the next generation of scientists. As Ken Calman said:

I was an oncologist, a cancer specialist. I know one or two people who have said 'I went into cancer medicine because of you', which is quite interesting... I suspect it’s partly the presentational thing. They like to hear about the difficulties, and this includes palliative care, which might be even more interesting, in a sense; the approach and the...non-financial personal rewards of working with people who are very unwell. It’s hugely rewarding. Sometimes, students and young adults just haven’t thought about it in those terms and they suddenly realise that, gosh, this could be quite an interesting area to work in.

Taken together, these three characterizations of science suggest that heroic archetypes such as the guardian, the explorer and the arbiter exist in science heroes’ communication with their audiences, and may be useful for achieving different communication outcomes. While these archetypes appeared more common in the presence of particular communication objectives, there was no evidence that they were used exclusively by any one subset of individuals within the cohort; rather, they appeared to be used selectively by many individuals depending on the different communication circumstances in which they found themselves and the objectives with which they engaged with different audiences.
5.7 Success, communication and the science hero

From the accounts given at interview a clear sense emerged of there being numerous benefits that arose from the processes of communicating in public, which included being able to make improvements to one’s work and ultimately, to one’s career path. As the biologist, Nancy Rothwell observed of the benefits:

It’s enormously rewarding, you get much better at public speaking, you get much better at public writing, but also you get ideas, you get feedback from the people you interact with who aren’t scientists. Now, of course, it is highly valued to do it. At one time it was something you did on the side. But I think it makes you more prominent in the scientific community. So when they’re trying to select people for a very important conference they’re more likely to know you than the others perhaps, and they may think, ‘oh well they’d be a good speaker’. So I think it helps in your career actually.

From Rothwell’s account one gains a sense of how influence and other career benefits might flow to those who actively seek to communicate with public audiences. As one becomes known for doing a good job of it, word of mouth spreads. People get to hear of it, and more opportunities for exposure follow. Clearly in the case of most science heroes, becoming known outweighs the risks of being unknown and of coming into conflict with both one’s peers, one’s audiences or both.

Whilst Rothwell’s account suggests that credibility arises from communication efforts when peers value it, there were also examples within the study of savvy individuals anticipating conflict around their work, and acting to divert or manage that conflict in ways that worked ultimately in their favour. The best example of this came from the Nobel laureates, Barry Marshall and Robin Warren, who at interview recalled the enormous effort required to have *Helicobacter pylori* recognised by the worldwide medical establishment as a valid cause of stomach ulceration. Noting that others had tried, and failed, to
overcome prevailing views about the survival of bacteria in the stomach lining, Marshall recalled embarked on an ambitious plan to prove his findings beyond reasonable doubt, which involved a concerted effort to get the story into the media and influence his peers:

I was taking shortcuts and doing all kinds of other things, and one of the things I did was I drank the bacteria... I treated people who walked in my door, I gave them some antibiotics, I developed a blood test, developed some diagnostic tests... thousands of doctors were testing out my treatment. And they'd typically test it out on their wives and mother in laws. And say, 'god, my mother in law, she was so cranky until I gave her some amoxycillin. She says her appetite improved, and she's been a saint ever since.' ...I had a following long before it was accepted dogma by doctors. And plenty of patients would have turned up at their doctor's practice with the news article, and said 'I'd really like you to try this on me'. And (some would) say 'Ah that's rubbish, I'm not gonna try that on you, you have to go to someone else.' Well, pretty soon the doctor in that town who did treat H. pylori had 95% of the patients...

Marshall’s full account, attached at Appendix 6, reveals much about the processes of communication embedded in his struggle for success. Echoing claims raised by Kuhn (1962) regarding the structure of scientific revolutions, it appears that Warren and Marshall’s discovery – despite being supported by a solid medical evidence base – was clearly not sufficient in and of itself to persuade a field of practitioners to agree with, let alone adopt it.

Having established the cause of and solution to what was then a common medical problem, Marshall corralled the forces of communication to work in his favour. He first developed a treatment, then offered it to previously ‘incurable’ patients, enabling positive word of mouth to flow within their social networks; he promoted it to physicians through papers and presentations, and enabled them to obtain pre-packaged treatments discreetly, increasing their effectiveness and thereby enhancing their reputations; and recognising that the media would tell
the story on his behalf, he made himself available for interview, helping the press to create news stories about the discovery that could be shared. Over time, those colleagues he persuaded before mainstream acceptance set in would go on to become the mainstream themselves; as he later said:

Early on, they would always delegate the Helicobacter research to the most hopeless, junior, unfunded doctor, from Timbuktu or somewhere. And then a year later they’d notice that he’d published a little paper, he’d be getting invited to speak at important lectures and conferences et cetera. And all those guys are now all the big professors in the United States. So if I go to the US now, I’ll be invited to black tie dinners, because the deans and the chiefs of gastroenterology are all these people who were in the controversial Helicobacter research fifteen years ago. Twenty years ago now. And now they’re all the professors of medicine.

Whilst Marshall and Warren were eventually successful in having their discovery accepted as scientific fact, it required many years of persistence before the work was widely accepted. Indeed, it was not so much an original idea, as one whose time had come: Marshall would later publish a book, *Helicobacter Pioneers* which revealed a long progression of other, earlier physicians who had struggled to have the same medical facts recognised.

Similarly, other accounts within the study, such as those of the astrochemist Gil Levin, shed some light on the difficulties individuals experience convincing their colleagues of new facts and the consequences of being right at the ‘wrong time’. In the following account, Levin described his experiences of the excruciatingly long timeframe over which he had defended an experiment to detect life on Mars and his determination to convince skeptical peers about what he felt that experiment had found:

All except a few of my colleagues rejected my data about the experiment. In recent years as more and more has been learned about Mars and as really extreme environments on Earth have been found populated with
microorganisms, they have changed, I have a goodly support now. Not the majority, but they do say 'he did discover life on Mars'... Until 1997, that’s 21 years after the experiment, I only said that the data were consistent with life. But in 1997 having reviewed, as I constantly did up to that point, new information about what we knew about Mars and of extremophiles on Earth, (it) convinced me that the scales had tilted. And I then declared that the experiment had detected life on Mars. It was quite frustrating. What I continually sought to do was to get the key critics to respond with specific reasons why they would not accept the data. And I never could get them into a real scientific discussion... not even in publications.

Levin’s account suggests that when one’s ideas lie outside the accepted scientific facts, disdain from colleagues can be swift, humiliating and persistent, and that attempts to gain acceptance can take many decades to achieve. The astrophysicist Paul Davies also recalled of this period that scientific acceptance of the very idea of life on Mars had changed over time, in response not just to new evidence but to individuals actively communicating about the idea. As he recalled, progress in this field could be charted by key communication events at which ideas were proposed, shared, refuted, refined and eventually accepted:

In 1983, I think it was, Martin Rees held a conference in Cambridge called From Matter To Life. A lot of people traced their interests in what we are now calling astrobiology to that meeting, and it was it was very influential. Freeman Dyson was there and ended up writing a book on the subject. Tommy Gold was there, and of course, he ended up discovering life in the deep subsurface. Sydney Brenner, who’d just taken over from Francis Crick, Graham Cairns-Smith, who had an idea that life came from clay. By then, you know I was really getting very interested...In the early 90s I sort of put two and two together and realised that these impacts could be powerful enough to splatter rocks around the solar system and convey life from one planet to another in the ejector, and couldn’t find anyone to take it seriously... but I thought it was a neat idea and just kept plugging away.
Then, Malcolm Walter who was at Macquarie University said will I go to a conference in London he was organizing and talk about it. So I did, somewhat to my trepidation because it’s a whole bunch of people who are basically what we would now call astrobiologists, but really geologists and biologists and those people. I thought, ‘well what would I make of this?’ Some of them thought, ‘well yeah, it seems pretty obvious’ and then others thought it was just totally crazy stuff.

I can remember we had a dinner with a somewhat rather distinguished British geologist, who chose his dinnertime remarks to pour scorn on this idea. Well, it was only six months later that Bill Clinton stood on the White House lawn and said that NASA has evidence for life on Mars in the form of the Allan Hills meteorite found in Antarctica. Although that evidence went away, suddenly everybody was talking about how life could pop around in meteorites. Now, it’s just part of the party line.

Davies’ example of the unnamed British geologist rejecting the idea of life on Mars, only to be proven wrong a short while later, tallies with numerous other examples of experts vociferously rejecting new ideas only to end up on the ‘wrong side’ of history.

5.8 Discussion

From the accounts given at interview, there appears to be a complex relationship between communication behaviours and success in science, which this study shows depends not just on personal characteristics such as curiosity and persistence or circumstantial factors such as luck, education and upbringing, but also on the formation of interpersonal relationships within one’s field, which ultimately assist in the development of lineage and positive relationships with one’s audiences, both expert and non-expert. Effective communication undoubtedly underpins the ability to develop and sustain interpersonal relationships, including those that play out in the public domain and that
develop, in some cases, into important galvanizing elements for new generations of scientists and more engaged publics.

As we have seen, choosing to communicate brings with it many benefits but also many potentially negative consequences. Amongst the most serious of these is a high likelihood of criticism, from a variety of sources, which can often be personally hurtful and to persist in the face of which requires both resilience and self-belief. Whilst some criticism notably arises from peers, who may disagree with an individual’s communication style or tone, feel that they have illegitimately claimed expertise or inappropriately crossed domain boundaries, stolen the limelight or failed to recognise the prior knowledge or expertise of others, or simply judge them as being wrong, it can also be from audiences, who may aggressively disagree with the direction or meaning of the content presented and with the presenter’s interpretation of ‘the facts’, particularly as these are most relevant to themselves.

Nevertheless, despite such negative consequences, individuals persevere – for the benefits of being heard surely outweigh the consequences of speaking out, and for those who master the art of it, effective communication enables greater influence, attracts resources and converts others to their cause – whether that be a call to action as in the case of those arguing for environmental conservation or better health outcomes, or simply persuading others to accept and take up their findings.

Self-experimenters, who place a conviction in their evidence at the forefront of their communications, may provide the most extreme example of this. For instance, by his own account Barry Marshall conscientiously and thoroughly experimented on himself with *H. pylori* and published the results, in an effort to secure the data needed to convince a disbelieving medical elite that what he had found was real. Such an extreme effort perhaps reflects the necessity confronting an individual who seeks to overcome an overwhelming opposition, in the form of prevailing scientific dogma and its influential, dedicated guardians.
As other notable examples from the recent past show, it also seems that such strategies can be used to reassure a skeptical public, who similarly form a rank of opposition to new evidence. Examples include self-experimenters such as Macfarlane Burnet, Ian Clunies Ross and Frank Fenner, who injected a live culture of myxoma virus and held a press conference on the steps of WEHI (Smith, 2010) Jonas Salk, who injected himself and immediate family with the polio vaccine (Mitka, 2005), and the former British parliamentarian, John Gummer, who attempted to allay public fears of contagion by feeding his child a beef burger at the height of the CJD crisis (BBC, 2000). In each of these cases, self-experimentation appears to have been deployed primarily as a case of ‘showmanship’, a persuasive mechanism intended to win support not from the scientific establishment but from the general populace, whose risk appetites at those times presumably did not extend to welcoming involuntary exposure to potential virus-related harm.

From such examples one can see that in the battle for primacy, there is more than scientific accuracy at work. Savvy individuals, fighting dogma, skepticism and criticism, also use communication to try and sway the outcomes of the scientific debate. Viewed through this lens, and as evidenced by the interviews summarised in this chapter, communication is a strategic tool that captures, convinces and cajoles. And it is a defining feature of many science heroes, whose skillful use of communication advocates for and builds bridges between scientific and social cultures.
6. Speaking of science: Science heroes and the art of communication

\[ \text{The art of communication is the language of leadership. – James C. Humes (2015)} \]

6.1 Chapter overview

This chapter summarises the key results as they relate to the third research question: **How do the norms of science intersect with heroic storytelling about science, and what consequences do these have for those individuals singled out as science heroes?** To answer this question, the chapter is divided into three parts that each explores a slightly different aspect of the results, which arose from questions asking individuals to recall their attitudes towards and experiences of communicating about their work.

The first part of the results summarises the significant motivations, opinions and philosophies of communication that were evidenced within participants’ accounts of personal approaches to communicating their work.

The second part of the results describes tensions experienced by participants in the process of communicating about science and highlights the presence of several significant problems that appeared to arise as a result of these tensions.

The third part of the results reveals the key communication skills reported by participants, which were identified from accounts of how individuals approached the technical aspect of communicating and the methods used to created communication content.

In summary, the questions exploring these topics elicited very rich and diverse data. Many different aspects of the art of communication were revealed, including fundamental motivations, opinions and philosophies of communication, responsiveness to different communication settings and
audiences, and the personal techniques and strategies for communication that individuals had developed and utilised over the courses of their lives and careers.

One important observation about the responses from participants is that their communication settings varied widely, both in the sense of whole-of-life experiences with communication and their professional opportunities to engage in it. Subsequently, there was extremely varied exposure to different communication environments and audiences within the cohort.

Another important observation is that a subset of the interviewees clearly had a very high degree of experience communicating with the media, and a subset of these were what might be called professional communicators: those who had been primarily employed within media industries as broadcasters, writers, presenters and/or major contributors of popular science content. These particular individuals were able to speak at length and in a very nuanced way about the realities, as they saw them, of working within the media to achieve their communication objectives.

A further observation is that within the accounts, there was clear evidence of tension between differing communication styles and settings for communication. In some cases there was a sense that particular styles, audiences and settings had greater status within the scientific community than others. An exploration of these tensions makes a case for the existence of communication norms and competing counter-norms. These findings are presented for discussion at the end of the chapter.

6.2 Part 1 - Motivations, opinions and philosophies of communication

I thought my life was mapped out. Research, living in the forest, teaching and writing. But in ’86 I went to a conference and realized the chimpanzees were disappearing. I had worldwide recognition and a gift of communication. I had to use them. – Jane Goodall (2004)
The comments of primatologist Jane Goodall, renowned for her ground-breaking research on chimpanzees, suggest that her approach to communication was informed by a powerful combination of factors – feeling compelled to protect a species she was passionate about, recognising the opportunities afforded by her global exposure and acknowledging her underlying ability to communicate effectively with others.

Goodall's comments bear similarity to those made by many participants in this study, who were asked to describe their personal approach to communicating about their work and encouraged to describe specific examples of effective communication. The participants reported many different attitudes and complex emotions towards their own communication efforts and, in some cases, also those of others.

An urgent need for change

Many people expressed the view that communicating about their work was an obligation born of the importance or urgency of the subject material; consequently there was a 'need for others to know' about their work. This view appeared frequently amongst those communicating about health or environmental matters, who in many cases had strong views about the significance of their work and expressed a high level of commitment to 'getting the word out'.

A number of participants spoke powerfully and with great conviction about their particular field and the need to increase awareness or create behavioural change in their audiences. Examples included Helen Caldicott, who spoke passionately about her work as a global anti-nuclear campaigner. Her approach to communication is aptly summarized in notes for a public talk promoting her book *Crisis Without End*, in which she describes her approach to communication thus:
The medical dangers of the nuclear fuel chain begin at uranium mining and end with either a massive nuclear power plant meltdown, a nuclear war or the many diseases and mutations in animals, plants and humans that will arise from the inevitable leakage of radioactive waste and the subsequent pollution of food chains for virtually infinity. I will walk people through this highly complex issue so that they have a deeper understanding of the genetic and carcinogenic dangers of the nuclear age. (Caldicott, 2015)

Caldicott’s comments suggest great conviction in the material and a planned and methodical approach to engaging audiences with it, to ensure that her preferred outcome – that of people gaining greater understanding of the dangers of nuclear fuels – would be achieved.

Similarly, although delivering a somewhat different message, naturalist Harry Butler’s approach to communication as presenter of the television series In The Wild appeared both passionate and systematic:

My mantra was ‘keep caring, it’s the only world we’ve got’ and that was the mantra that every signature, every book, everything came out with... What I was trying to say to people was ‘you don’t need a Harry Butler to enjoy the bush. You can do this in your backyard. You can turn over a stone, you can see... where the spiders live, where the lizards live, what lives in the garden... you do not have to be a gung ho naturalist on safari, bush safari, walkabout, to go out and do it. You can do it right here’. That was the attitude... (that) the ordinary fellow said ‘well yeah, I could do that’... The second thing that came out of it was I almost always finished the show by saying ‘now put it back’... native plants and animals were sort of left in situ. And that came over, people remember me, they remember ‘oh, what did Harry Butler say? Put it back’. That message came through.

While Butler expressed his desire to show the ‘common man’ the opportunities that everyday life present to engage with nature, of greater significance in his account is his desire to create a ‘deeper understanding’ in the audience of what
they should do. This concept of fostering understanding and awareness was a very common theme amongst the interview participants.

**Persuasion**

Many participants saw communication as a way to influence key audiences within science, or to persuade other specialists to share their point of view. For example, the biochemist Gil Levin recalled making persuasive attempts to be involved with the Viking mission to Mars and then later, to persuade colleagues at NASA that photographs shot of the Martian surface were in fact showing signs of microbial life:

My immediate reason for going to Mars was that it represented an opportunity to demonstrate the system I had invented to detect microorganisms quickly. And I demonstrated it first on Earth, but I wanted it to be used by the state health departments... And when I had an opportunity to meet with a NASA administrator I asked him if, it just dawned on me that night, if NASA was going to look for life on other planets? And he says, ‘well we’re getting ready now, we just hired a guy as our chief biologist, why don’t you go down and talk to him?’ So then I sold them on this idea using this method to go to Mars...

When I went back to JPL several months after Viking concluded, I decided it was so frustrating I was going to look for other possibilities to support what my experiment had found... So I looked at every one of the 10,000 images that the Viking 1 and 2 took. And suddenly I realized that these images had colour, it wasn’t as NASA had published that the entire landscape was monotonously orange-red. I found green, olive, ochre, yellow and I took these pictures... and made slides of them. I went down to NASA headquarters to show them and said ‘no there’s something wrong here, there are colours on Mars and what’s more I have two images here of the same spot taken a year apart... And it looks like there are some spots, greenish in tinge, and it looks like they’ve changed shape in the course of
this period'. So I showed them, they got 11 guys together in NASA headquarters, and I showed them these slides. There was deep silence. Finally one of these guys said 'come on Gil. You know they're all just grey. I don't see any colour there'. Finally one of them stood up, Walter J Grobowski and said 'come on guys, that's enough.'

And I went straight to my son's elementary school, he was in 4th grade, and I went to the principal and said 'I've got some slides of Mars, would it be possible if my son's class would be interested in seeing them?' She said 'absolutely' and she took me in ...and I showed the kids these slides...And then at the end I said 'well what do you see?' They said 'rocks' and 'there are some different coloured ones'. And they saw the green and the different colours. And I said 'thank you very much' and I picked them all up and I went home with my sanity. These kids were frank enough to say what they saw. NASA wasn't.

Levin's account suggests a very strong determination to have his work recognised and taken up by his peers; his conviction was so strong that he proceeded to seek confirmation from an independent audience that he was not alone in what he saw. The behaviours he reported suggest persistence, passion for his subject and a high degree of self-interestedness. Levin also appears motivated to persuade as a result of a strong conviction that he is correct – both in terms of his experimental methodology and his findings. Such self-belief and determination is reminiscent of the 'stick-to-it-ive-ness' attributed to the nineteenth century inventor Thomas Edison (n.a., 2014a), understood as a fundamental component of genius alongside hard work and common sense (Fort Myers Press, 1920).

Creating conversations

Some participants felt that rather than a specific course of action being required from their audience, the purpose of communicating was to enable the public to assess the value of publicly funded scientific work. As the sustainability expert and policy-maker Ian Lowe observed:
There’s still a feeling in the scientific community that you’re almost letting the side down by explaining science in plain English, rather like a magician revealing how the three card trick is done. If you reveal the secrets of the trade then you’re taking science off its pedestal of expertise. But I don’t think it is demeaning or belittling... for most scientific research you really should be able to explain to somebody in plain English what you’re doing and why it’s important. All the scientific research I’ve done has been publicly funded and it seems to me part of the quid pro quo is that if some of your research is funded by the public the public have a right to know of what you’re doing and why you’re doing it. The old adage is 'they who pay the piper call the tune' and I think even if the public aren’t calling the tune they should at least hear the music.

Others felt that conversations were required about the broader social and political issues confronting science. Some felt that failures to anticipate and mitigate the complex social and physical impacts of new technologies had increased mistrust in science over time, and that as a result people were more skeptical about its benefits. For example, as the molecular biologist John Coggins said, more active communication was needed, in order to reassure the community and ensure greater engagement with the issues of the future:

We need to somehow recapture public confidence, and I think part of that is being more honest with the public...we really have to work hard to make sure that bright young people realize there are wonderful challenges in science and huge problems to solve, and they need to get stuck in.

Coggins’ latter comment highlights one of the frequent motivations for communication cited within the interviews: a need to engage the next generation of potential scientists with emerging opportunities in science and motivate them to undertake STEM careers. Amongst those raising this as an important motivation was the former science teacher and broadcaster Aubrey Manning, who observed how changing cost pressures within universities had caused anxiety about the ‘pipeline’ of young scientists:
There is now a complete mindset in the scientific community that we do not have enough youngsters coming through to keep all of the academics in work, we don’t have enough youngsters to come through to keep the lights on, even... A lot of our infrastructure, our technological infrastructure is ageing and there is nobody to keep it working because nobody has been recruited in the last 20 years. We’re just panicking basically. The government here has put on a huge advertising campaign. They're even putting adverts in the cinema for youngsters to say ‘please do science’, with a James Bond film... It's panic.

Manning’s account hints at an immense communication effort to popularize STEM careers and raises the possibility that the scientific community feels pressured to communicate with this target audience, perhaps in ways that it has not previously.

Similarly, James Mather’s recollections implied a concerted effort towards inspiration, flowing from the publication of scientific results and in particular, imagery derived from and relating to space missions. As he recalled, the material NASA produces contributes greatly to aspirational goals amongst young people in relation to science careers:

NASA works quite hard to get scientific results out and part of our charter from the government is to give our results back to the public and help inspire the public to the next thing, whatever it may be. So we work quite hard to get our pictures and our messages back to the public that paid for everything. That’s a good thing. But some kids find that this is the ticket for them that shows them that science is exciting and leads to the next generation of brilliant leaders. So we need them and so NASA’s moon programme was really important for that. A lot of kids grew up saying 'I want to be an astronaut' and now they're doing something, probably different, but they've still got their start in science because of something about the spectulars that we do.
Changing communication contexts

A large number of participants felt that the pressure to communicate had increased over time. In addition to the need to increase STEM participation, a contributing factor was a perceived change within the scale and obligations of universities. As parliamentarian Ron Oxburgh explained:

I think things and situations in universities have changed profoundly today. It’s really with the expansion of universities worldwide... and the pressure on universities to do research, that the amount of money that they spend has become large enough fortreasuries and governments really to care about it and [put it] under scrutiny.

Comments from the geoscientist Larry Edwards support this view; as he observed of changes at the University of Minnesota, the approach had shifted in favour of increased communication:

I have been on tenure committees and promotion committees and back 20 years ago in our college, it was pretty much all research and that’s really changed... if you’re a wonderful communicator but not productive in research you still won’t make it. But if you were outstanding in research but couldn’t communicate you also wouldn’t make it... I would say that the university is after recognition for its faculty and for itself, basically. Minnesota (is) the public university and so there’s some advantage for us to have some visibility in the State media and viewed as having a good positive effect on the State in general, so that that would be linked to money from the legislature, which we are in desperate need of, particularly right now. So there is some link there.

Edwards’ comments convey a sense that engaging the media is a necessity for publicly funded institutions, which rely on maintaining visibility in part through the communication activities of their faculty. Others made similar observations, including the oceanographer Simon Boxhall who noted the critical role public
communication played in engaging students considering enrolling in the university:

We have two motivations. One motivation is that we want the public to understand about the marine world, about their interaction with the marine world. But we also want to sell us. You know, we rely on those lovely bums on seats for degree courses. The more that we have University of Southampton or National Oceanography Centre at the bottom of the screen, the more that prospective students and parents go, 'ooh, okay!'. Now, if they’re unclear – and this week in particular it's results time, people are making their decisions as to where they’re going – it does make a big difference if you see the place you’re thinking about appearing on the news, as it gives you confidence that this place knows what they’re talking about because they’re on television... it’s very clear that the five minute slot on say a chat program or a three minute slot on the news has far more impact than, say... an article with Nature. Now it doesn't mean to say we should dictate terms with Nature because for us, I mean, that’s probably what we want... but in terms of attracting young people, students ... they’re watching television; they're watching daytime television in particular. I mean, one of the biggest feedbacks we got from students was viewing a program called Richard and Judy, which is a daytime chat television program. I don’t think I’ve ever watched it but we got huge feedback from students who saw it. It's that sort of thing, unfortunately, which gets students attracted to us.

Boxhall’s comments suggest that media appearances could bring benefits to the institution, helping shift the balance in its favour when trying to attract new cohorts of students and increasing its credibility as a destination of choice.

**Influencing public policy**

Other participants felt that there had been important changes in the public policy environment, where communication was a key method for ensuring
greater transparency and clarity about the purpose and outcomes of science. This appeared particularly pertinent for those working in publicly funded research where the taxpayer had a ‘right to know’ what their money was spent on. Communication was sometimes seen as a vehicle to engage with policy makers and ensure that they had access to good scientific evidence as part of the policy development process. As Scotland’s former Chief Scientist, Anne Glover stated:

Most (government officials) in the UK are not scientists nor do they have a scientific background. So the challenge there is also to make it relevant and to use science to identify where there are problems, but also provide scientific methodology and approaches to be able to mitigate the effects of various problems and provide solutions for the issues that we have to address in the modern world.

Glover’s views speak to the impact of ‘evidence-based policy’ approaches by government, and the attendant rise in communication pressures for those carrying out publicly funded research. As Glover also observed, research has profound implications for society and scientists are not necessarily always the best judges of what is appropriate and what’s not:

I mean why should politicians use evidence, and we are always asking them to use evidence in their policy making - why should they use evidence if we don’t have some responsibility towards making that evidence accessible to them? You know they have to do a bit of a translation job. And I think that’s one of the roles I feel I have, as a translator of science, to whoever my audience happens to be at the time... I’m quite comfortable doing that, and I hope more scientists move in that direction in the future.

Glover’s comments were echoed by those of the Nobel Laureate, Harry Kroto, in a 2013 conference address:

Scientists have a responsibility, or at least I feel I have a responsibility, to ensure that what I do is for the benefit of the human race... It is important
that we try to point out facts to help those in power to make decisions.
(Kroto, 2012)

Similarly Larry Edwards, who felt strongly that his work understanding global climate systems had a role to lay in public policy development, said:

In my work in particular I think I have something to contribute ultimately to policy discussions...and to our future as a society. So I want to get some of this stuff out... in the broader context of how climate might affect our future and so on... there's also the climate issues, the environmental issues in general and there's the evolution issue and how one teaches that... some of our knowledge is really important to be shared with others.

Edwards' comments suggest that his peers feel compelled to communicate when the policy agenda is significant and scientific knowledge clearly has a role to play in its development.

**Responding to demand**

In a number of cases the need to communicate was more closely linked to the need to meet public or media demand for information. For example, Ron Oxburgh stated that he felt “as long as people want to listen, I really should talk” while astronomer Neil deGrasse Tyson said:

Philosophically I see myself as a servant of the public appetite for the universe... I write a book every now and then and there’s a marketing strategy where I’m inserted into the talk shows and that sort of thing, but that’s 15 percent of my total encounters with the public. All the rest are people wanting to learn about the universe from me... if I had my choice I’d just stay home and play with my kids... I would not go out to the public, I would not do the interview, I would not do TV...

Whilst Tyson’s account suggests a certain degree of weariness at the responsibilities of communicating to public audiences, others also working ‘on
demand’ elaborated strong feelings of enjoyment in doing so. As the UK’s Astronomer Royal, Martin Rees, put it:

My main subject area is astronomy and cosmology and is one in which the public does have a lot of interest. So I’ve done quite a lot of writing of articles and books and lecturing on those subjects. I personally enjoy doing it. Indeed, I derive much less satisfaction from my work if I can only talk to a few fellow specialists about it. I enjoy being able to explain the key ideas for a wider public...

Rees’ comments suggest that public interest in the cosmos creates demand for communication activities on the subject, and that his communication outputs are multi-faceted and diverse. Furthermore, communicating about fundamental ideas in science is a source of great enjoyment for him, particularly when the audience is perceived to be coming to understand it for the first time.

Personal enjoyment

Like Rees, many other participants described feeling great enjoyment and deriving personal satisfaction from their communication activities. In one example, the naturalist and broadcaster David Attenborough described his enjoyment in making television programs that shared his excitement in the natural world and enabled him to explain the meaning of what he found there:

I had a biological degree but I started as a general television producer and I produced programs of all kinds and I like producing programs, because programs are fun. I tend to suppose that the urge to communicate is a basic human urge and one that’s deep in our psyche and there is a pleasure in communication. And having seen something, many of us including me want to go and tell somebody that they’ve seen something remarkable, and what making television programs enables you to do is precisely that... And of course part of the fun is making sure that what you are communicating is correct and that includes not, as it were, the basic
fact but the understanding of what it means. So the more you can do that, the greater pleasure you get from doing so.

Attenborough’s account conveys not just a sense of the pleasure and fun to be had in communicating, but in communicating accurately. It also reveals something more: an almost child-like compulsion to share his personal delight in and insight of the natural world. In another particularly pertinent example, inventor and science presenter Jonathan Hare summarized his experiences of communicating about the ‘wonder substance’ buckminsterfullerene, the subject of his PhD, beginning under the tutelage of his supervisor, Harry Kroto:

Going out and sharing that with people and giving workshops has probably been the most important thing in the last 10 years to my development... We had lots of schools phoning up and saying, ‘can someone come and talk?’ My boss used to do a lot of them but he got to the stage where there was one hundred a year phoning up. So he said, ‘you should do some of these’. So I started going out into schools and giving talks and getting very nervous. The first 10 or 20 were bloody awful. I was so nervous. But I had a topic which I loved. So I wasn't nervous of giving the talk. I was nervous of standing up in front of people... But because I was very confident, very happy and enthusiastic to talk about this thing - I’d been on a Horizon just for a little clip, I had lots of exposure because of the molecule - so I was very confident... Every time I’d do a talk, I’d do some new overheads so I had something new to show, for me. So I ended up having thousands of overheads and so I could just put a talk together about something. I’d just say, well what I’m interested in today - and I’d talk about that. It was just so lovely to be able to go in and talk to a crowd of people...because the buckminsterfullerene had the chemistry, it had the architectural stuff of which were buckminsterfullerene domes. You had atoms and molecules. You had allotropes. You had nanotechnology. You've got the biological interest that these things spontaneously form very complex chiral structures... it’s interesting from astronomy, material science, biology, architectural, you got the mass of these things which is
very beautiful and simple [as well]. So suddenly I had this beautiful topic to share and it was absolutely lovely. Then it was fun to do it with very small kids: primary school, GCSE and A Levels and adults; getting and realising that all these things were interesting in their own right.

Hare’s comments convey a strong sense of personal fascination and appreciation for what he has learned about the world and the delight he takes in sharing what he sees. It is clear, too, that he values and pursues opportunities to engage others with the subject material. His enjoyment appears to have two loci: firstly, in the sense of personal reward for communicating, which manifests as a positive and powerful sense of ‘having fun’ and secondly, in the changes he sees occurring in his audience as they, too, start to ‘get’ the beauty, complexity and interest of the world. Their views, newly formed as a result of his intervention, provide a powerful reinforcement for the act of communication. Ultimately, Hare is motivated to prepare further material – ‘just for myself’ as he puts it, but also ultimately for the audience.

6.3 Modes of communication

In describing their approaches to communication, interviewees described a wide range of past communication experiences, which fell into a number of common categories including:

- Presenting information or research results to peers and professional audiences, such as colleagues within the day-to-day work environments and experts at specialist conferences and meetings.

- Teaching students in formal learning environments such as schools and universities, or as part of training programs.

- Public speaking and demonstrations to lay or non-expert audiences, often as part of public engagement activities such as science festivals, outreach
activities such as student engagement programs and in informal learning environments such as science clubs, museums and observatories.

• Interacting with the media and media audiences, either when participating in television, radio and print media interviews, as a presenter or broadcaster of science programs or when participating in media events giving exposure for recent work.

• Communicating with others in online forums and social media, where the professional or intellectual background of the audience was not always known.

• Corresponding with people who wrote letters or emails to them.

One might observe that such communication experiences are not uncommon; indeed, they feature often in the professional lives of most, if not all scientists and other STEM professionals. Participants also reported a number of very common communication practices that one might consider to be routine; these included the use of visual presentation tools, such as Microsoft Powerpoint™ and other visual aids, and preparatory activities such as scripting talks or rehearsing them in advance.

In and of themselves, such activities are unremarkable as a feature of contemporary professional life. What is remarkable, however, is the unique and often strategic approaches to engaging with audiences that were reported by the participants, often accompanied by descriptions of distinct communication styles and the motivations behind their use.

Observing the expert

It was apparent that the science heroes participating in the study were in many cases keen observers of their audiences, with advanced insights into the utility and advantage of using particular communication styles. In many cases, this awareness appeared to have started early in their careers, through exposure to
the influential communication styles of those around them, and in particular the communication behaviours of their own heroes and mentors. For example, Robert Winston recalled the combative style of one key mentor, Donald Hunter, who was then the senior examiner at the Royal College of Medicine:

He told this story in his own defence, which was nice. He was a nice man. Because he was massively interested in, as I said, industrial diseases, on one occasion he had this huge instrument on his desk and he pushed it toward the candidate and he said ‘tell me about that’. The candidate said ‘well sir, this is a Dorset Remington Dallinger’ and Donald Hunter said ‘well my boy, you’ve done very well. This is a Dallinger but it’s a Partington Dallinger’. He said ‘no sir, I’m really sorry, it’s a Dorset Remington’. And Donald said ‘don’t argue with me. It is a Partington Drill from Johannesburg.’ The candidate said ‘well you must forgive me, sir. My name is Dorset. My father designed this drill’.

This impression of two individuals battling to convey their unquestionable expertise is somewhat reminiscent of an observation made by science historian Trevor Pinch about a certain communication style observed amongst scientists jostling for position during periods of scientific controversy. As he wrote:

They ride in from the elite schools such as CalTech or MIT, and their job is to use a quick theoretical argument, a back of the envelope calculation, to shoot down the luckless experimenter. It’s a particular style they cultivate. Quick on the draw, the catchy metaphor, never getting defensive but always managing to sound as if they speak for everyone (Pinch, 1992, p. 495).

Together, these accounts characterize a style of communication that might best be described as ‘assertive authority’; designed to convey confidence, demonstrate intellectual supremacy and perhaps most importantly, to impress upon others the correctness of the speaker’s view.
A feel for the audience

Like Hare, many participants revealed strong personal feelings of enjoyment when communicating about their work, using expressions such as “getting a rush” or “it’s a real buzz” when the audience “got the message”. Such descriptions are strongly suggestive of communication as a highly rewarding experience for the presenter, which for many seemed to derive from their success at building a rapport with their audiences and pleasure in being able to attract and hold attention. As Ron Oxburgh explained:

There are some occasions when you can actually grab the audience and really pull them along...The last time it really happened was about 18 months ago. It was a hot day, in Wellington at the university there and the big lecture theatre was packed with people sitting down. It was obviously a sympathetic audience; they wanted to hear what I had to say. But by the end you could feel the whole (audience) was there, it was an amazing feeling. It’s a combination of you and of them, time and the (size of the) lecture theatre - you could have the same group in a lecture theatre ten times the size and there would be none of this...the thing is that an audience gets a great deal from each other while they’re listening to a presentation. You know, something comes across - and I’ve seen it in audiences myself...The first thing a student does, if they don’t understand what’s on the board, they look around. They want to find out whether they’re the only one who is finding it difficult, or whether everyone else is. That's actually quite important signals, it’s quite important signal for the lecturer too if the lecturer can pick that up. Again, there is a sort of an indefinable sort of spirit, ethos, interaction, between the audience, and then between the audience as a group and the speaker. That is something which is very hard to define, but it’s something to do with personal interaction.
The molecular biologist Nancy Millis similarly felt that the success of her interactions with an audience relied on having a high degree of sensitivity to their needs:

I’ve always found it difficult to understand stuff myself, so it takes me a long time to understand stuff. So because of that when I’m trying to talk to students I have an understanding, or a feeling, for why they might find this concept difficult. So I look at them and if you see the whites of their eyes going like fish, you say ‘right I’ve failed again’ and you try another go. So you’ve really got to be sensitive to your audience, you’ve really got to be able to look at them and get a bit of a feel as to whether they are saying, ‘I can’t stand a bar of this old chook’… You’ve got to try as best you can.

Similarly, the zoologist Millie Rhodes recalled her efforts when tutoring undergraduate students at the University of Melbourne:

You’ve got to think of different ways (of explaining it). You can say something once and then say it again and then you see people’s faces kind of go, ‘oh, I understand that’… Some sort of expression comes over their face and they don’t even have to say ‘I get it’… You can see (it) straight away and then you can say, ‘now you tell me’, and then they’ll usually be able to tell you.

Rhodes’ account portrays her communication as an empathetic and nuanced practice, with success predicated on the audience making the right connections between new and existing information, often facilitated by her own repeated efforts to present the information in different ways. Rhodes suggests that audiences signal their level of engagement and comprehension to the presenter, and that successful communication comes from accurately ‘reading’ the audience and responding to their signals, both verbal and non-verbal.

Many other accounts suggested that positive rewards flow during communication to both the presenter and the audience; certainly, a large number of participants
used terms such as ‘fun’, ‘rewarding’ and ‘satisfying’ when describing communication that elicited a positive response from their audiences.

Taken together, these accounts suggest a communication style that might best be described as ‘observer responder’: finely tuned and designed to respond and adapt to the changing needs of the audience.

**A feel for the story**

Many saw communicating about their work as being essentially a storytelling form in which they, the storyteller, were trying to communicate the most important ideas in ways that would capture and excite the imagination of the audience. The renowned ethnobotanist and *Time* magazine ‘Hero for the Planet’ Mark Plotkin described it thus:

> I want to put them in the zone. I want everybody at my lecture in a trance, okay, because that’s where deep learning takes place. I want to turn out the lights and get them to look at the pictures and take them into the jungle with me and transport them to the magic place where they get a sense of that magic and they want to protect that magic. Secondly, I want to inspire people to try and do cool stuff. ...I want to give people an idea that there’s more to life besides medicine and law and pre-dad’s business. I want to give people who are older than I am a sense of well, the rainforest disappears, we may lose the cure to aids or cancer or other diseases that haven't come out yet and wouldn't the world be just a boring place if everything went extinct except for rats and pigeons?

A similar passion for storytelling was visible in many of the accounts given at interview, both in terms of what individuals said and how they said it. Participants frequently spoke fluently and passionately in the interview context, using evocative and succinct phrases, and peppering their responses to questions with anecdotes and humorous asides.
Many participants also detailed aspects of their storytelling behaviour. A common theme was storytelling structure, which for many involved building the narrative as one would a thrilling story; a journey with a beginning, middle and end, and a sense of the ‘rising action’ common to popular storytelling forms (n.a. 2015c, Dictionary.com). One participant recalled building up in his introduction to achieve a ‘So what? moment’, when the reasons for the work would be made clear, following which, further details of the work could be revealed progressively, leading to a climax or main point (the ‘eureka!’ or ‘a-ha!’ moment) before finally revealing its significance and impact in relation to the bigger picture.

A large number of presenters described their communication as ‘painting pictures’ for their audiences in order to position the work in a particular context, such as how it had addressed a bigger problem and why that was important. In many cases this literally involved presenting pictures, with a number of participants reporting that they used striking visual imagery to ‘capture the imagination’ and provide a memorable backdrop to their communication.

In some cases, participants described their use of dramatic narrative in detail, and many interviewees displayed a sense of awareness of how to manipulate or influence the emotional state of the audience for maximum effect. For example, some of those working in climate change or environmental communication seemed keenly aware of the potential emotions that could flow to their audiences when presented with overwhelming evidence of destructive processes affecting earth systems. Tim Flannery, for example, talked about the need to personalise the information, making it relevant to the audience and tapping into their emotions. He also observed that painting pictures about tomorrow can be very uplifting, by giving people a sense of control and participation in their destiny. Others, including Kathy Sykes and David Suzuki, spoke of framing or positioning the information as a personal issue, by talking about impacts on society or on relevant ‘like others’, such as the next generation of family – an approach designed to persuade the audience that this was, indeed, something they should care about.
Collectively, such approaches to communication might best be described as ‘narrative transformative’: designed with a big-picture message in mind and intended to transport the audience into new realms of understanding, often using emotional hooks to achieve an impact.

**Conflicting communication styles**

In many accounts different and apparently dichotomous communication styles were noted as being used, with consequences for how and when they were deployed. Simplistically, the tension between the styles could be described as a conflict between generalized, issues-focused and person-centred approaches as opposed to precise, fact-focused and contextually abstracted approaches.

Again highlighting the existence of differing communication styles, many participants felt that there was a need to employ different approaches according to the communications environment in which one found oneself, contrasting the styles needed for successful peer-to-peer communication with those needed for successful public communication. For example as the climate scientist, Anne Henderson-Sellers, said:

> I see someone like Jim Hanson and he's very much my hero, he's very good indeed. And what he does, Jim is meticulous. He does the experiment or the analysis or the observations himself, with his team at the Goddard Institute of Space Studies, and then he reports on that. And he's pretty much unwavering. I mean he doesn't commentate on other people's views, he doesn't participate in things like the IPCC, he simply does the piece of science investigation that he thinks is important... and then he reports on that. He doesn't get drawn into anything else and I think well, maybe that's a very clever way to go. Then I think, on the other hand, someone like Steve Schneider who is also very much a hero of mine, is very articulate and Steve can take on the arguments that various people have portrayed, and then kind of analyse those and engage in the debate almost at the level a QC might.
Henderson-Sellers’ account contrasts the careful, meticulous and focused style of Hansen with the passionate, rhetorical style of Schneider, which one could interpret as a contrast between fact-focused and idea-focused communication, echoing Pinch’s observation of competing communication styles amongst science heroes (Pinch, 1992). Indeed, whilst both individuals are undoubtedly expert in their grasp of the scientific material and feel strongly about engaging their audiences with the science of climate change, it is Schneider’s highly articulate style that offers a point of comparison. By this account, while Hansen does not ‘commentate’, Schneider surely does, mastering the art of arguing with conviction, in order to participate in what Schneider himself has described as a public debate in which scientists are akin to warriors on an uncertain battle field (Schneider, 2015). Seeing participation in the fight as crucial, he said:

Just because we scientists have PhD’s we should not hang up our citizenship at the door of a public meeting (n.p.).

A feel for the material

One important idea raised repeatedly by participants was the concept of communication as an art form requiring repeated and sustained practice to get right. Many commented on the frequency with which they gave lectures or presentations and crucially, the extent to which they were prepared go to ensure that their material was well presented. As Mark Plotkin said:

I have the gift of the gab, but you know what, I give hundreds and hundreds and hundreds and hundreds of lectures and I watch other people delivering, what they’re doing right and what they’re doing wrong... Storytelling is something that you continue to learn. I don’t think that I tell a story the way I did 25 years ago, because people have short attention spans. There’s some people you can enthrall sitting around the camp fire but other people have to have images and other people have to have music and so the shrinking attention is something that you have to deal with as a
storyteller... So you have to know your audience and commit to always refining and improving.

Similarly, Ron Oxburgh revealed having a deep interest in how to communicate the most important and useful aspects of his work:

I do have a real interest in how you get complicated ideas across. The belief that nearly all very complicated ideas can be reduced to simple elements which people can grasp. So I do spend quite a lot of time in thinking about lectures. I never give the same lecture twice...but I use some of the same material over again. I spend quite a lot of time in devising dramatic ways of showing the important elements of what I’m trying to get across... I think that it is a combination of having what I hope are relatively simple arguments, that are reduced to their bare bones, and then really going for, where possible, a dramatic and logical way of getting them across. I think that's quite important.

Like Oxburgh, some saw themselves as translators of science, required and able to transform the dense, technical jargon of scientific disciplines into more readily understood language. Many saw this transformation of language as key to engaging successfully with non-technical audiences, in some cases commenting on the difficulties of establishing a common understanding between different specialists from various fields, and the communication techniques they used to bridge that gap. For example, as the development conservationist Harry Butler recalled in regards to presenting introductory lectures to new arrivals on Barrow Island, who were predominantly oil and gas industry workers with varying degrees of technical expertise:

Oil men, when they talk drilling oil, use words that have quite specific meanings and they know what they're talking about. So when I’m talking to them I talk in that language. But when I’m talking to a mixed audience... they've got a world of background experience and they’re likely to have a low tolerance of apparently being talked down to. The lecture I give...starts with a world image, the problems that face the world...
environmentally... Desertification, salinity, soil acidity, loss of potable water, loss of species, El Nino... I’m using images which they have grasped from the media they are accustomed to, plus their daily work...and I’m building from that into the particular jargon of our specialized lives, which is oilfield.

Butler’s account reveals a mastery of both the material and means by which to communicate effectively, gained through more than 30 years of experience communicating on, and about, Barrow Island. The impression given is that of an individual able to move easily between different audiences, in part through his use of multiple, interconnected stories that progress from broad themes aimed at building a common understanding of the challenges, to the delivery of detailed information about maintaining the island’s conservation status, suitable to the audience. There is a sense that both the content and language of his communication are finely tuned to have impact; in particular, that by ‘speaking the right language’ he is able to establish his credentials and establish a position of relative authority with his audiences.

Collectively, such communication approaches might be best thought of as ‘esteemed expert’: designed to demonstrate deep mastery of the subject, in ways that are simultaneously impressive to and accessible by the audience.

6.4 Tensions between communication styles

Butler’s account seems to suggest that scientists and laypeople may have very different views of what constitutes the ‘right language’ when it comes to science communication. And, as Anne Glover revealed, the process of simplifying scientific concepts can be quite problematic:

(It) offends a lot of scientists actually, because they feel that, for example, you should never refer to bacteria or yeast as bugs because that’s not a scientific term. Well, it’s true, but everybody knows what it means if you talk about bugs; at least a non-science audience does...
Such observations hint at the presence of a significant tension for those communicating science, between the need to maintain a very specific scientific understanding on the one hand and the need for breadth of understanding on the other. Indeed, when the different communication styles reported by science heroes are contrasted with one another, it appears that there are many almost polarizing characteristics and values embodied within them.

Broadly speaking, narrative and responsive styles appear to rely on dramatic structures, personalised, revelatory and passionate language, aspirational scope, human-centeredness and selective use of terminology to convey a particular or ‘curated’ meaning. Such characteristics appear to stand in almost diametric opposition to the values apparent in other communication styles, such as accuracy, specificity, detachment of the speaker from the subject material, logical structures, high intellect and a focus on scientific rather than social meaning.

The apparent difficulty of balancing these competing values when trying to communicate is perhaps best summarized by the physicist and television presenter Kathy Sykes, who said:

I know the power of storytelling but I’m much more inclined to go for, to try to explain ideas. I kind of have to remind myself, ‘no, no, no Kathy, tell the story. Make it human’.

### 6.5 Part 2 – Tensions within science communication

There was also a sense from these concerns that being singled out and having prominence as a hero of science could potentially bring with it negative repercussions of both a personal and professional kind. Examples were sometimes provided of other scientists to whom this had happened; those who had experienced grave consequences as a result of attracting ‘too much attention’, particularly through media appearances.
One area of questioning was around the individuals’ experiences of appearing in the media and their scientific peers’ reactions to that media presence. In most accounts was a suggestion that speaking about science risked incurring a backlash, as this example from science broadcaster James Burke shows:

When this whole (TV) thing began, back in the 60s, I got letters from my pals at Oxford saying, ‘I see you’ve become a charlatan.’ And I wrote back saying, ‘Yeah, that’s true, I have’ – Because, what else was I going to say? Back when I started, the old educational establishment regarded people who spoke about subjects in which they didn’t have a PhD as charlatans. I mean, I remember I made a real mistake of going back to college once, at Oxford, to give a talk on being a broadcaster – silly sod that I was, I mean, why would I, what a sucker... and at the end of the dinner speech, some guy at the back stood up and said, ‘Have you got a doctorate in any single thing you’ve mentioned tonight?’ And I hadn’t mentioned anything in which I had a doctorate, and I said ‘No’, and he said, ‘Well, why did you mention these things?’ And fortunately, people threw bread rolls at him and he sat down. But that’s the way it used to be. So, early on, my relationship to the scientific community was bad. I'll never forget some person, some scientist, when I made Connections, which was the first major series I made, she said ‘Outstandingly and extraordinarily vulgar’ Period. And I don’t think she meant vulgar, in the sense of the crowd; she meant vulgar...

A small number of participants also mentioned concerns about how and where their views expressed at interview might be published and whether they would be personally identified. These tended to be those with a significant media profile, who had previously experienced public criticism from their peers, inaccurate media coverage of their work, or both.

Such experiences – and the resulting perception of those experiences by others participating in the study – hint at the presence of behavioural and communication norms within science, that may sit adjunct to those proposed by
sociologists such as Anderson et al. (2010) and Merton (1957, 1973). At least some of these concerns seem to relate to the norm of humility and its competing counter-norm, primacy, and these possibilities will be discussed in more detail at the end of this chapter.

6.6 The problem of divulgation

A desire to ‘humanize’ scientific processes and knowledge came through strongly in many of the participants’ accounts and such descriptions are reminiscent of the phenomenon known as ‘divulgationism’, a term used by the naturalist Jan Cousteau to describe the storytelling technique of her father-in-law, Jacques Cousteau (Sharpness, 2007).

For example, in his 1971 book Life and death in a coral sea, Cousteau wrote: “It is all strange, unearthly yet familiar. Strange because the sea, once it casts its spell, holds one in its net of wonder forever” (Khatri, 2012; p.56). Cousteau’s use of evocative, emotive language to convey his personal sense of wonder and delight pervades his communication in film and literature; indeed it is his ability to communicate in this way that appears to have contributed enormously to his status as a science hero. As the film editor and motion graphics artist Jeff Trussell wrote of Cousteau, for the My Hero Project:

When Jacques-Yves Cousteau died on June 25, 1997, the world lost more than just an esteemed biologist and oceanographer. The world lost its greatest guide of the chartless realms that make up the planet’s oceans. Through his documentaries and books, Cousteau contributed more to our understanding of the oceans than almost any other person (Trussell, n.d.).

Cousteau’s relationship with the natural world seems embodied in his style of communication and many online sources have repeated the claim that Cousteau’s ‘divulgationist’ storytelling changed the way that science documentaries were constructed in the second half of the 20th Century.
However, as some commentators have noted, his use of storytelling actually presented something of a double-edged sword:

As a storyteller but also a conservationist, he had trouble keeping his constituents happy. Scientists accused him of showmanship, critics accused him of faking scenes, and networks demanded he keep his films full of intrigue, not Earth-saving rhetoric. (Jacquet, 2009)

This observation succinctly highlights some of the tensions affecting communication by those in the public eye, as evidenced by the observations made by a number of the science heroes at interview.

The interview cohort contained a number of individuals who either self-reported or were reported by other participants as having been criticized for their public communication. Some participants recalled specific instances where they had personally been subject to direct criticism from their peers, while others recalled specific instances where they had witnessed their peers being criticised by colleagues, or had heard stories about criticisms being levelled at others. In some cases, participants expressed direct criticism of their peers for their communication activities, some of whom were also participating in the study. In addition, colleagues and acquaintances of the researcher also expressed some criticisms of particular individuals’ communication styles.

Those whose communication was identified as being problematic included Robert Winston, Kathy Sykes, Johnny Ball, Helen Caldicott, Tim Flannery, Harry Butler, David Suzuki, Karl Kruszelnicki, David Attenborough and Simon Singh – notably, all individuals with a high public profile. A number of participants also cited other well-known individuals as having problematic communication styles, including the late zoologist Steve Irwin (a.k.a. The Crocodile Hunter), who some felt attracted criticism for his ‘egotistic’ personality and ‘inappropriate’ style of wildlife broadcasting, and the late astronomer Carl Sagan, whom it was noted suffered vilification and rejection from some of his peers for embarking on science popularization activities. Indeed, biographies of Sagan such as those by
Davidson (1999) and Poundstone (1999) appear to confirm that Sagan’s membership nomination to the prestigious National Academy of Sciences was rejected on the basis of his communication activities. As Benford (1997) wrote:

In the early 1990’s, the National Academy of Sciences held its annual election to membership... Each section of the Academy votes separately on all candidates, and the astronomy division voted the fellow in. But there were negative votes from other divisions, notably the particle physicists. They disliked his public persona, some said. They complained that he was arrogant and an egomaniac, and said he was really not up to caliber, despite his fame. Clearly, envy played some role. Rumors flew. Rarely is a candidate turned down, but it happened that time.

Such an historical example strongly suggests that public communication activities may pose a substantial risk to the scientist who pursues them, and it is fortunate that the study cohort contained a relatively large number of science popularisers whose own views and experiences of life in the limelight could be explored in some depth.

One area of questioning was around the individuals’ experiences of appearing in the media and their colleagues’ reactions to that media presence, and several interesting observations arising from the accounts given at interview:

First, all of the individuals reported as having been criticized had a high media profile and were very experienced at working with the media.

Second, the criticisms were not universal. Some of the individuals’ communications were praised or complimented by others taking part in the study, and desktop searches revealed that these individuals received many compliments for their public communication.

Finally, the criticisms were diverse and able to be categorized into three major areas: issues with personal communication style, such as the manner in which someone spoke; issues with balance or objectivity, such as appearing biased or
too obviously trying to achieve a particular political or social outcome; and issues with accuracy. In the latter case, individuals were criticized for public communication about subjects in which they were not regarded as being expert, or not expert enough compared to the complainant. In some cases, individuals previously respected for their specific domain expertise appeared to have lost that respect once they were perceived as having commented on areas beyond it.

Within the data, of particular interest is the experience of Tim Flannery, about whom Jacquet’s critical observations of divulgationism might just as well apply. An acclaimed zoologist, Australia’s former Climate Change commissioner and a passionate communicator about the science of climate change, Flannery has become a polarizing figure in the public domain as well as some scientific arenas. In the aftermath of publishing the book *The Future Eaters*, his narrative style was praised in the media as “science popularization at its Antipodean best”, whilst Flannery himself was likened to “Indiana Jones, but with the credibility to match the flair” (ABC, 1998). However, while many scientists have sung his praises, others have expressed disquiet – some of it deeply personal in tone, as this extract from the *Sydney Morning Herald* shows:

"Just because a guy is well known does not mean he knows what he is talking about," Dr Stephen Wroe, a palaeontologist at the University of Sydney, says. "I've got a fairly cynical view of Tim. He's an opportunist. He knows climate change is a buzzword, but a few months' work does not make him an expert." Dr Judith Field, an archaeologist at the University of Sydney, doesn't hold back, either: "Tim doesn't let the facts get in the way of a good story. He does a lot of broadbrush stuff, with broad consequences, and some of it is just plain wrong." And another archaeologist, Jim Allen, of La Trobe University, made the observation a while ago: "I wish I could be as sure of anything as Tim is of everything" (Sheehan, 2004).

Such comments suggest that Flannery’s scientific peers have a number of professional issues with the style of his communication, including concerns
about a scientist speaking outside his area of expertise, a sense that as ‘a newcomer’ to the field Flannery is not sufficiently knowledgeable in contrast to others, nor is sufficiently committed to the field to be taken seriously. These attacks on Flannery are also highly personal: he is unflatteringly characterized as over-confident and an egotist, an individual who uses the opportunity presented by the newsworthiness of climate change to elevate himself in the public eye.

Two other significant criticisms are also visible in these reported comments: firstly, the claim that Flannery’s style appears to be ‘more about the storytelling than it is about the facts’, and secondly, the suggestion that Flannery is willing to compromise accuracy for the sake of ‘a good story’.

Elsewhere, Flannery’s communications have also been criticized by members of the media and the public. In contrast to an earlier description of Flannery as a ‘showman’, the conservative journalist Christopher Pearson later expanded on his comments to describe Flannery as “more shaman than showman, a folk mystic and prophet for the New Age remnant” (Williams, 2007).

For most accomplished scientists, such terms would usually be considered highly derogatory, yet in Flannery’s case, these particular comments are relatively moderate compared to the descriptors used by other commentators in the public sphere, including “charlatan” (Crocker, 2012) and “professional scaremonger” (Bolt, 2010).

What is one to make of such critical views of Flannery? And how is it that such an accomplished individual can be simultaneously respected and despised? The answer may lie in conflicting communication norms within – and about – science.

6.7 Media hero: science zero?

Many of those publicly attacking Flannery, including Bolt and Pearson, are journalists and media commentators writing for a general readership. Flannery’s view is that while such personal criticism from these sources is undeserved and
indefensible, it is also understandable in light of the subject material with which he works. As he proposed in an interview at the Mudgee Reader’s Festival in August 2014:

The fact is, we’re in the middle of a very vicious battle about climate change... There are a lot of vested interests in the fossil fuel industry who want to keep making those big profits year after year and want to slow down the uptake of renewable [energy]. People who speak out are inevitably drawn into it... I just point to the facts. If people write to me, I do engage with them and say, 'show me [where I've said that], I'm happy to have a discussion with you about it'. No one ever can (show me).

(Virtue, 2014)

Flannery’s comments suggest that he feels the criticisms levelled at him stem from his efforts to communicate about climate change, rather than any inherent inaccuracies in his work. In his depiction of climate change communication as a battle, played out in the media, in which powerful forces are in conflict, there is also a sense that some degree of personal injury is to be expected amongst participants. Subsequently, one needs to have a thick skin, patience and persistence.

It is beyond the remit of this thesis to investigate Flannery’s claims as they relate to climate change communication as a contested space; however recent scholarship by authors such as Hamilton (2008, 2010) confirm that this is a complex topic worthy of further in-depth study. Nevertheless, it is pertinent to consider at least one key aspect of the scenarios raised: the role and relationship of the media in relation to science communication.

The difficulties of balancing a media profile with a scientific one are perhaps best summarized by an ‘ordinary scientist’, entomologist Colin Bower, who commented on an article about Flannery published by the Australian news site, Crikey:
As a biological scientist I have never been a fan of Flannery and his outpourings. Flannery is an ‘ideas’ person, rather than a deeply analytical scientist. His career success is based on the development of headline-catching, often controversial conjectures that capture the popular imagination. His writings scratch together evidence that supports his ideas, ignoring everything that doesn’t. He seems to have little interest in testing his own hypotheses scientifically, leaving that to others. In the process misconceptions are propagated that become fixed as facts in popular culture... (Hamilton, 2009)

Bower’s comments are interesting in that they suggest a tension between communication styles and scientific behaviour. In his argument, Bower characterizes ‘outpourings’ and ideas as running counter to analysis, while conjecture and argument are presented as poor substitutes for the thorough testing of hypotheses. There is a criticism of Flannery’s arguments as selective and biased, and that the ‘real science’ is left to others. Overarching these complaints is a concern that through his ‘headline-catching’ communication, Flannery is focused on capturing the public imagination rather than revealing scientific truths, and that in the process he is facilitating a popular culture that is not grounded in scientific facts.

Such anxieties are reminiscent of the issues raised by science heroes when discussing their own experiences of working with the media, and their observations of the issues confronting scientists in similar circumstances to their own.

Participants’ experiences of interacting with the media

It was clear from the interview data that interactions with the media are a common feature in the professional lives of most science heroes. All participants reported having some experience communicating through the media, with most having experience of working with print, radio and television journalists. However, the degree of media experience differed for each individual and was
influenced by the extent and importance of their professional achievements, their career stage, their professional roles and responsibilities, their communication skills, their past experiences of doing media interviews, and their confidence with and degree of comfort in speaking to the media.

In many cases, individuals felt that in the early stages of their career they were focused on ‘doing the work’ and on gaining the core competencies that would enable them to successfully compete in the scientific or technical world. Most conveyed the impression that opportunities for early-career researchers to engage with the media were also rare; in some cases, individuals recalled that they had little desire or incentive to do so, with few supervisors encouraging them to speak with the media. Instead, if and when opportunities arose, more experienced scientists and research leaders would tend to carry out any ‘media duties’.

However, the situation appeared to change once individuals had received public accolades of some sort. These included on publication of significant results (such as making a major discovery, published in a prestigious journal), on receiving a major prize or award (such as being awarded a Nobel prize or Fields Medal), on publishing a major work designed for non-expert audiences (as occurred for Tim Flannery, on publishing *The Future Eaters* or Lawrence Krauss, on publishing *The Science of Star Trek*), after making a well-publicised public appearance (for example, presenting a Faraday Lecture at the Royal Institution in London) or following a television appearance. Indeed, increased contact with the media appeared to be common after significant events, with many reporting that they were now ‘on a list of experts the media calls whenever they need someone’.

**Participants’ feelings about interacting with the media**

Interviewees expressed a range of reactions to seeing themselves represented on television or in print, which varied from cautious enjoyment to outright hostility. One frequent complaint was the lack of control the individual had over how their material would be used; some observed that they had spent hours participating in filming, only to be included in just a few seconds or minutes of the final news
story. Others felt that their efforts to engage in accurate communication through the media were often confounded, unfairly, by journalistic or editorial processes that selectively used their material to tell a different story to the one the individual had intended.

For many, lasting negative impressions were gained from working with the media. As Earth scientist Wally Broecker put it:

I never watch any of this stuff they do, because it annoys me... Once I did six-hour news in New York and I'll never do that again. Because I did watch that and they just chopped it up and used me to give credibility. They used my name. They talked about all kinds of things then flashed my face. I didn't like that, because that means I'm giving credibility to anything they talked about. Those newscasts at that hour can be really bad.

Other participants' accounts suggested that there were 'good' and 'bad' journalists and that the quality of science content varied with the nature of the program and the individuals involved; as Ron Oxburgh described:

Radio and television, [they] tend to be more pressurised. The people you're talking to tend to have an agenda. The really good television or radio interviewers listen to what you say and then it becomes a ping-pong and the return has something to do with the service and what have you. The poor ones have a list of questions which they go down and there's no [matter] of the next question fitting into the previous answer. On certain topics, if you know you're going to be interviewed on this, some information that I don't carry in my mind - my memory - all the time, and I may want to refer to it, I look a few things up just to remind myself if I'm asked about detail – or I'll look an idiot and say, 'well I don't know, I can look it up later'. But that's about it.

Oxburgh's comment is interesting in that it suggests journalists may pose questions that lie outside the individual’s sphere of expertise, and that one may
'look an idiot' unless well-prepared to answer them. Indeed, similar experiences were reported by a large number of participants, including many of the Nobel Laureates, who recalled being 'expected to know' or 'drawn into commenting' about subjects beyond their areas of expertise. The physician Ray Tallis perhaps best summarized these problems, by observing:

That's the problem... you make your reputation in a particular field whether it's history, philosophy or science and then everybody wants to know what you think about Madonna and what you think about trade balance in the Third World and so on - and your views are just as good as the chap standing next to you in the pub... people do invite you to comment on things about which you know very little, and the temptation... having had years of not being heard, or being heard but only in the pub, the idea of being heard by 4 million people is very, very seductive... the media give you an opportunity to be heard above the crowd.

Tallis' further comments also provide some insights into why experts may find the published comments of others, less expert than themselves, so infuriating:

You have a passionate belief that your views are correct, and you're surrounded by idiots. There's that frustration, I guess, of hearing things that you think are wrong.

This combination of passionate belief in oneself and in the accuracy of one's own knowledge perhaps helps to explain the antipathy observed towards highly visible individuals such as Tim Flannery, from others working in the same or similar fields.

**Communication benefits from working with the media**

A number of participants commented on the fact that they had learned and improved their communication skills through talking to the media. The neuroscientist Larry Farwell, for example, observed the techniques used by media
outlets to convey information about his discoveries and described his learning curve when it came to improving his own communication techniques:

I have been very favourably impressed with the way the media have handled brain fingerprinting because it is not an easy subject... they have been able to portray the connection between science and the impact science has on people’s lives. They are very good at doing things that are going to be emotionally moving to their audience... So they’ll go from the science to a serial killer gets put away, or the science to a guy walks out of prison who has been in there for 23 years for a murder that he didn't do. They've been able to convey the excitement and the human impact. So I've been very impressed with what the media have done. Another thing that the media have done is they have inspired me to be able to express myself in a way that is simple and clear because if you’ve got - well PBS did a one hour special. If you've got an hour you can really expound in considerable detail and you can lead somebody along. But if you know it’s going to be a two minute news spot... I've had to think okay, if I have only a few words to express what I do and why it's important and what it means to me how am I going to say it in a few words that capture the essence?

In Farwell’s account there is a sense of a communicator striving to improve his own skill base, and to be more adept at expressing his admittedly complex science, in ways that focus on what is important and essential about the work. Importantly, it highlights his awareness of the need to ‘say it in a few words’; that is, to simplify the content in such a way that the key point or significance of the work is clear.

Other participants observed that communicating with the media enabled them to connect with the wider audience and make their views heard, and in doing so influence scientific or social debate. One pertinent example of this view came from science presenter Kathy Sykes, who said:
My big motives are, while I am here on this planet, trying to change things...for the better... This whole thing about the way we use science can profoundly mess up the planet and people, and it can help. What I do is all about trying to help us make wiser choices. In terms of that agenda, what I need to do is reach scientists and policymakers, others as well, and the media. So being in the media obviously helps and presenting means that when I’m meeting policymakers, often they know who I am. They wouldn't have known this little prof at Bristol University but because I've done stuff on telly - when the CST turn up to meet Tony Blair and we've got an hour with him in the morning, he says, ‘oh hi Kathy’. In that way of ‘I know you’, even though there's no way that he remembers me from having met me before. But he's saying that in a way that I just think 'right, you've seen me on television. You feel like you know me even though you don't’ and that's a massive way in. So I feel like in my agenda of wanting to change stuff, being on telly makes a massive, massive difference. That goes also though with being a massive risk. Because I know after the first series of alternative (medicine) stuff, everywhere I went people would say, ‘oh you're the one that...’ or ‘I know you’ or... I care about my privacy and my space and stuff, really badly. So in some ways, doing telly is one of the stupidest things I can do. But the extra access it gives is phenomenal.

Like many others, Sykes' account suggests that there are both costs and benefits to obtaining a media profile; in this instance, her loss of personal privacy and exposure to critical or invasive remarks appears to be directly mitigated by a gain in personal influence and access to decision-makers. And for many of those motivated by aspirational goals such as 'changing the world' or 'making a difference', this particular sacrifice, at least, appeared to be worth making in light of the benefits it brings.

**Material benefits from working with the media**

Access to influential others was not the only benefit reported by those participants who had gained a strong media profile. For those whose
achievements were particularly well-publicised, a common experience was to appear as a keynote speaker or ‘headline act’, at events in which their appearance was a major attraction. A number of individuals in the study clearly had the public status of celebrity and in such cases, public events at which they featured might frequently be ticketed and charged for. This was the case for many well-known personalities within the sample, including David Attenborough, David Suzuki, Neil de Grasse Tyson, ‘Dr Karl’ Kruszelnicki and ‘the Mythbusters’, Adam Savage and Jamie Hyneman.

For such individuals, public appearances were a ‘fact of life’ when maintaining a public profile or persona, and events were usually highly publicised and coordinated by supporters such as personal assistants, media officers, public relations agencies or commercial event organisers, which would generally recover costs from the paying audience. However, others in the study were relatively new to the experience of ‘being famous’ and their recollections provided a fascinating insight into both the material benefits and the processes of becoming a public science hero.

For example, a number of Nobel Laureates recalled that on receipt of their awards they found themselves to be world famous, quite literally, overnight. In most cases, whilst previously being well known within their respective fields, they had enjoyed public anonymity. Based on their accounts, their previous media experience was generally not extensive and they did not regard themselves as having any celebrity status. The sudden receipt of such a globally publicised award therefore meant they were thrust into the media spotlight from a position of relative obscurity.

Their accounts suggest that immediately on becoming a Nobel Laureate, the media interest is both intense and persistent; this reality seems confirmed by the annual reports of the Nobel Foundation, which in 2014 reported:

> When the Laureates are announced in October each year, it propels researchers, authors and peace advocates into the spotlight. The world’s
attention is momentarily directed towards scientific progress and
humanist questions that affect us all, either directly or indirectly. The
Nobel Prize attracts enormous media attention. As an example, during
2014 over 50,000 articles were published in digital media. (Heikensten,
2015, p1.)

With only six Nobel Prize categories awarded annually, a conservative estimate
suggests that the 2013 Nobel Laureates were the subject of some 8000 media
articles in each category. Even accounting for the prizes’ distribution across 12
individuals and one organization, this is a huge number of media contacts per
individual by any reckoning.

Whilst some of the Nobel Laureates interviewed for this study depicted this
media attention as being ‘exhausting’ or presenting ‘a steep learning curve’, for
the most part the individuals were happy with and gained benefit from their
encounters with the media. Apart from the material benefits that came with the
Nobel Prize award, Nobel Laureates also experienced a range of other benefits
from their media exposure and instant celebrity. These included paid speaking
engagements, greater professional and popular recognition, supplementary
funding for research, new employment opportunities, further publishing
opportunities and tenured positions at the institutions of their choice. Some
noted that their home institutions also publicised their presence and
achievements and became gatekeepers and coordinators for their ongoing
communication efforts, even long after their official ‘Nobel year’ had drawn to a
close. This was the case for the 2013 Nobel Laureates Barry Marshall and Robin
Warren, whose communication efforts continue to be supported by the Office of
the Nobel Laureates in Western Australia, which was formed in response to their
award.

Many other participants in the study had a somewhat lesser media profile but
also appeared very much in demand by audiences as public speakers; this
included ‘public experts’ such as Ron Oxburgh, Ray Tallis and Tim Flannery,
whose public appearances might also commonly be organized by agents,
universities, festivals and learned bodies. A shared observation by some participants was that presenting at a well-publicised event generally led to having a greater public and media profile and often resulted in further invitations to speak at events and conferences. Thus a sense was gained that attracting some publicity provided the basis for further publicity.

6.8 Developing the profile of a public expert

The role of public expert appeared to develop when individuals were publicly associated with important knowledge, which occurred when scientific or technical knowledge was made easily accessible (for example, through presented in public talks or popular publications) and as a result of making media appearances – with one often leading to the other, and vice versa. One fascinating example came from the lead inventor of DNA fingerprinting, Alec Jeffries, who recalled:

The media played a colossally important role in everything that we've done. Because without them, fingerprinting would've just languished around as an academic curiosity. It would've got nowhere. The sequence of events that got it out into the public was: we came up with a chance discovery. We published our first paper in Nature. That was then picked up by a science writer, I think in The Guardian and then that little article where he speculated on my speculations about identification of family relationships. That was then read by a lawyer in London, who then promptly wrote to me. He said, ‘look we've got this immigration dispute. Is there anything you can do to help using the technology? I don't understand in the slightest’. That proved to be the world's first DNA case - an immigration dispute. Without the media there, that communication wouldn't have happened. That would've been the problem. Then all the subsequent press coverage - I've had far more than my fair share of press attention. I thought DNA was going to be a nine day wonder at the beginning. The press interest in it is as strong now as it was 25 years ago. It's simply because there's just so many cases involving DNA. Nobody on
the news now even bothers to say what DNA is. It’s just, oh well, this
particular case was solved by DNA or a DNA match. So it’s entered into
the absolutely popular language. But I suspect that a lot of people don’t
really understand what’s being done with this technology.

Yeah, so there’s been a huge amount of press interest... we basically had a
good news story, you see... Let’s just take our first immigration dispute. If
it had shown this kid was wrong, it would’ve been the first anybody
would’ve heard about DNA. It would’ve been all over the media with this
poor little kid being dragged, kicking and screaming to Heathrow and
dumped on a plane. Deported from the country, all because of horrible
DNA. That would've been the starting story. It would've been a disaster. As
it was we showed that he was okay, that the Home Office officials who
didn’t believe his story were wrong. So here was science supporting the
small individual who’d done nothing wrong whatsoever, and beating
bureaucracy. That’s a really good story. That’s the sort of stuff that the
papers like to get their teeth in.

So we've had these good news stories right the way through. So it’s really
been very positive. Even on the more recent debates about how the
National DNA Database is being used. Is it right to keep all these
hundreds-of-thousands of entirely innocent people on that database and
so on. But even though I don’t work directly in forensic DNA anymore, I’ve
always kept a watching brief on that. If I think things are going wrong, I’m
very happy to talk to the media and to express those concerns.

As one might expect, being broadcast in the national media had the effect of
increasing individuals’ public profiles, which many felt had led in turn to further
broadcast media appearances being offered. Robert Winston gave a thorough
description of this phenomenon, when summarising the parallel development of
his medical science and broadcasting careers:

I had done one television (show), which was the first caesarean section
ever filmed on television. That was transmitted in black and white and it
was notable because during the caesarean section, as I was delivering the baby through the open abdomen, I had this terrible sensation that every surgeon dreads, which is the sensation of the drawstring on your pyjama trousers coming loose... I was wedded to television after that.

...(I had) 30 or 40 publications over a period of time. One of them, which was quite revolutionary, was noticed by a television producer... he said 'I'm making a program for the BBC about what medicine will be like in the year 2000, in 25 years' time and I've been reading those papers that you've been writing. They're really interesting. They're very unusual. They're quite revolutionary, the thinking'. I thought 'yeah, you flatter everybody like that'.

...But anyhow we made this program together. We wrote it together and it was broadcast in 1975. It won the annual science fiction award for best television program or best film for the year in Berlin. That kind of got me noticed by the BBC and then they offered me a series to present, which was Your Life in Their Hands. I did about six series of that, so about 30 odd programs... It was watched by vast numbers of people, nine million people, which was pretty good in BBC Two... That was the first time that anybody had seen operations in colour on television, so it made quite an impact. I've looked at those programs and I was an appallingly nervous presenter, I mean absolutely embarrassingly terrible I think... I was so awful... Anyhow it lead to more and more and then after about six series... actually it started interfering with my research.

So I really concentrated for the next 11 years on really gaining a body of research and the research went well. I mean I was very, very lucky... and then I went back. The first big one was Making Babies, which was kind of smash hit success stuff. It was seven programs and it was very much warts and all dilemmas and stuff like that, associated with what I was doing in the lab and elsewhere. That had huge, huge figures, so that's The Human Body, which of course is watched by one-third of the British population - which is amazing and won about 25 international prizes, three BAFTAs,
two Emmy nominations, Peabody award. Then there was a series of programs... some of which are better than others, some of which I’m proud of, some of which I’m not very... They’re all portraying science in different ways really, to a lesser or greater extent.

Winston’s account details the progression of a dual career in both biomedical science and science communication, with a fair degree of movement occurring back and forth throughout his career. It is clear from his account that he enjoyed communicating, had many opportunities to do so, and felt that ‘one thing led to another’ in terms of his television career. However, it is also clear that his communication work had implications: there was a sense that doing ‘too much’ television could take time away from conducting research, which he identified as being critical to establishing and maintaining a successful scientific career. Winston’s television appearances appeared to be underpinned both by his previous on-screen experience and by his professional status as an expert, gained and maintained through publishing high quality research. Both had relative costs and benefits that he was clearly sensitive to, and these played a part when he made career decisions.

**Issues of quality**

In addition to the issue of quantity (i.e. ‘too much’ communication leading to ‘not enough’ science) there also appears to be an issue of quality, as evidenced by a tension between the ‘right’ and ‘wrong’ sort of communication. Winston’s account hints at this, in referencing television series that he was ‘less proud’ of; other participants described some of their media appearances as ‘embarrassing’. Sometimes the quality issues were associated with behaviours by the media; a number of interviewees suggested that some media outlets were ‘terrible’ and that only some media interviewers could be regarded as ‘proper journalists’.

Accuracy appeared to be a key issue for many of those making such assessments, with complaints such as the media ‘sometimes gets it wrong’ or ‘took my comments out of context’. The social entrepreneur Rory Stear, who observed that
some degree of inaccuracy in media reporting was to be expected, gave a particularly succinct example of this:

I think about the best media article we ever had was Fast Company put us in their Agenda issue in about 2000. They used to have Agenda issues, which were basically their Oscars, and we won the whole area of social responsibility and social justice. The journalist who did that, travelled with me for some time, travelled with various people in our organisation. Had access to the Roddicks, Terry Waite, all the various people associated with us. I reckon they got it about 80 per cent right and that was somebody who’d put hundreds of hours into really understanding us. So almost every article I ever read is not accurate.

While Stear viewed inaccurate reporting as being ‘just the fact of life’ many others felt personally targeted or victimised by inaccurate media reporting, for example when the media did ‘a hatchet job’ when characterizing their motivations or reasoning or publishing stories that broke an embargo. For example, as physician Hugh Montgomery recalled:

I’m increasingly cautious... I’ve been phoned up, could I give an interview, could I give some advice on X, Y and Z? You do and then what you find is that something appears in the press as a quote, which isn’t anything to do with what you said. It’s not something you would ever say. It’s not something that could even have been misinterpreted. All they wanted to have been able to do is write in their notebook that they phoned you and then put a quote out and then say, well okay, bring the lawyers on if you want to. Some of those things can be professionally embarrassing but also dangerous in their communication. So that’s irritating.

I’ve had information leaked to the press from a prepublication... Our first gene for human fitness, we were very keen and we’d done that with access to the British Army, which had been difficult to get because they just want military research and you’ve got some sensitivities to overcome. I was phoned up by a journalist who’d somehow got hold of the data and not
from me or my group. I don't know how they got hold of it. They said, ‘I hear you’ve been doing secret research for the British military to select special forces’... I said, ‘well that’s not true’. They said, ‘well I’ve got the data in front of me’, and read me data out. I said, ‘well the data is certainly correct but that wasn’t the purpose of doing it. In fact this is charity-funded health research, et cetera, et cetera’. He said, ‘well fine, I’m going to press on Sunday’. I said, ‘well I hope it would be appropriately managed but it shouldn’t go to press because it might pull the paper and it’s important and now you know the story you’re planning to run isn’t true’. He said, 'I'm not interested in the truth, I'm interested in selling newspapers'.

Such tensions may help to explain why some interview candidates felt that the expansion of one's media profile could be dangerous in terms of scientific credibility, and potentially lead them into conflict with one's peers.

Another aspect of perceived quality related to the understanding – or misunderstanding – by scientists about the intended audience for media appearances. As Jonathon Hare recalled:

University (people)- they respected Rough Science. But Hollywood Science, they didn’t like it... I was very embarrassed about it at the start... Because coming from an academic atmosphere, when I saw them I thought, ‘oh my God!’ But now I realise it was never meant for university people was it? It was meant for those people who left school, who thought they hated science; and for them it worked 100 per cent perfect...

Hare’s account suggests that the understanding of quality in science communication may differ depending on whom one believes it is for; in this case, to the academic science sector Rough Science – in which a team of scientists pool their knowledge to complete a series of tasks (2015b) was a ‘better’ sort of communication than Hollywood Science – in which two people recreate Hollywood film scenes, to see if they work from a scientific perspective (Baram-Tsabari, 2010).
Yet from Hare’s point of view Hollywood Science was far more successful, based on the responses of its intended audience:

I’ve had more people come up to me about Hollywood Science even though it hasn't been on for five years, than Rough Science. I had really lovely emails, the most wonderful emails from people who were on the beach with their autistic sons who never could get anything out of them and they watched Hollywood Science. They loved it and they spent the day on the beach doing experiments… I meet people who love Rough Science or love Hollywood Science, not too many like both. But I meet a lot of people who really loved Hollywood Science, thought it was great... and the producers knew that. They’d done it and they got it spot on.

Exactly why different audiences favoured one programme above the other is not clear from Hare’s account, but is a subject worthy of further interrogation. For the purposes of the current discussion, suffice to say that for individuals such as Hare, media appearances increased visibility and enabled both positive and negative judgements of quality to form. From his account it seems apparent that the purposes of the communication were not always clear to those academic scientists watching it. These factors may help to explain why some scientists make unflattering criticisms of others who are communicating about science in the public domain – in some cases, their judgement may simply relate to a lack of understanding about the intended audience for that communication.

Communality versus individualism

One observation that may be made of Hollywood Science is that it featured only one scientist, working with an entertainer to devise a series of experiments and calculations. Hare could therefore be viewed as the only ‘real’ scientist on the programme, in contrast to Rough Science, where he was one of five experts.

At interview, several participants suggested that there is a tension between the demands of the media for a singular, identifiable expert or ‘talent’ to act as the spokesperson for science-related stories and the realities of contemporary science
practice, which is simultaneously both communal and individualistic. As the physician and Nobel Laureate, John Sulston put it:

It used to be absolutely disgraceful to have anything to do with the media at all and... where I was at the LMB we didn't do media, it just wasn't the done thing really... It was regarded as a distraction and there is a genuine sense in which you have to be very careful. Science is quite deeply and in essence a communal activity. Anybody who displays themselves as being 'the one' in a particular field has to be awfully careful to make it clear that they know very well that they're riding on the backs of others and people constantly do this. I mean it was Newton I think on 'standing on the shoulders of giants' and you know lots of phrases like this that help to put the point and it is really important to know this is a very social activity. On the other hand, you know, particular ideas and so forth come from individuals. I mean the sort of tension that you're talking about, it displays very well in Jim Watson's lovely book The Double Helix for example and Jim is really keen to make it clear that he put the bits of the puzzle together on the table, and of course in the early versions also he was very, very disgracefully down on Rosalind Franklin.

Sulston's comments highlight a number of issues, one of which is the tension between recognizing science as a communal endeavour that inherently relies on the work of others, while simultaneously also depending on individual endeavour to succeed.

His account also highlights the case of fellow Nobel Laureate, James Watson, whose 1976 account of the discovery of DNA has been described as 'a classic of nonfiction writing... brilliant and racy and gossipy, and full of questionable truths' (Rutherford, 2014). In the decades following its publication the book has been both praised and criticized by the scientific community: revered on the one hand for its humanistic and vivid description of the scientific process and despised on the other for its egotistic tone and diminishing portrayal of fellow
scientist Rosalind Franklin, upon whose work the discovery of the structure of DNA also relied.

Sulston also draws attention to the difficulty individuals face when drawn into speaking outside their areas of expertise. While Watson successfully weathered the criticisms of his book throughout an auspicious research career, in 2007 he fell spectacularly from grace, by publicly asserting that the racial inferiority of black people was a fact and would ‘soon be proven’ through genetic evidence. Overnight, Watson became a pariah amongst scientists and non-scientists alike. As Steven Rose, a professor of biological sciences at the Open University observed:

“This is Watson at his most scandalous... If he knew the literature in the subject he would know he was out of his depth scientifically, quite apart from socially and politically (quoted in Milmo, 2007, para. 14).”

Watson’s litany of errors was long. Amongst them was the claim that his views were founded on scientific fact. In doing so, Watson appears to have simultaneously revealed his lack of subject expertise and contravened a number of important values within science, such as the honest, transparent and thorough use of supporting evidence when claiming scientific fact.

One wonders about the circumstances in which such an experienced scientist came to make these errors; Watson’s views were not able to be investigated for this study as he declined a request for interview. However, within the study there was one individual who had also suffered a ‘fall from grace’; the presenter Johnny Ball, who reported enjoying a thriving career until he communicated ‘in the wrong way’. According to Ball, the fact that he remained optimistic in the face of dire climate change predictions and advocated for the efficiency of power stations rather than solar systems meant that he had become persona non grata. As he described it, this was a fundamentally a problem of communication:

“...To be depressed about the possible future, to be depressed about the future of the world, is not the way to educate children. That’s all we’re
getting: seven or eight out of 10 science projects in schools these days are environmental projects. It’s not the kids’ fault and you can’t ask the kids to save the world. You ask them to become scientists, engineers, technologists and save the world from the top. For instance, generators in power stations across the world... are so much more efficient... Fifty years ago, if you’d said to engineers you could achieve that, they’d have said ‘no way’. They couldn’t see it... So you’re getting 62 per cent more energy out of the fossil fuel that we use... Now that is wonderful news... But all we’re doing is depressing our kids and telling them to switch their standby lights off... I’m terribly - I’m totally committed to doing that, to the point of making myself unpopular with the Royal Society, who tried to temper my speech.

Ball’s account hints at a possible conflict between different communication styles and highlights the difficulties of managing the differing communication needs of public audiences and the scientific community.

6.9 Part 3 – The art of communicating

In contrast, many of the acclaimed individuals who participated in this study demonstrated a keen awareness of different audiences and distinguished them as having specific and distinct communication needs. A number felt that in order to prove that something was important, they first had to make the audience believe it was important. And to achieve this, they reported using a variety of tactics.

Some started with knowledge of the audience, suggesting that they would try to imagine what the person would want to know, what language they would be comfortable using, and what concepts or ideas might naturally be understood, based on everyday/lay examples. In one such example, Tim Flannery talked about the importance of using entertaining, relevant language appropriate to the audience:
When you’re a scientist you use language to state very clearly and unequivocally what you've discovered... whereas if you're trying to communicate with people, the nature of the language you use is unimportant. If you speak boringly, it puts people off... I normally imagine the audience being like my mum. She's interested in these issues, but didn't have much schooling [around it] ... It has to be somewhat entertaining (as quoted in White, 2014).

Some participants commented on the need to observe the way audiences responded to communication and to be aware of the tone of voice they used. One observation was that ‘if you get the tone wrong, your audience will switch off’. Similarly, hitting the ‘right tone’ was thought by many to be important and something that was learnt through practice. Techniques used to achieve this included being positive in attitude towards the audience and treating them with respect, particularly when they asked questions.

Most participants talked about the need to communicate at a cognitive level that was suitable for the audience, by modifying their language and the use of examples their audiences could relate to. For some, the needs of the audience are the primary focus; in one pertinent example, Alec Jeffries recalled:

If someone said, ‘would you like to give a lecture? oh but there won’t be time for questions at the end’, then I will refuse to do it. Because I think that's the point where you can really - particularly (for) a lay audience - start finding out where the problems are in terms of understanding. But also let them set the agenda. People have got a real interest in genetics. It may be a broad interest. It may be a personal interest because they have particular family having some disorder that they want to know about. You can use the lecture as a way of just getting people to open up and then to try and address those concerns.

For others, it was a meaningful way of persuading audiences to consider alternate viewpoints to those they might already hold. As David Suzuki described:
...there's often resistance to my ideas because it involves a change in the way they see the world and it will involve changes in their lives, and there's resistance to that. But when you relate that to, look, it's not about you, it's about your children and grandchildren, then they get it, and it's much more palatable ...Basically, if I'm trying to make a point, I try to tell it in a way that immediately becomes obvious to the person listening, oh, because they can relate to that in terms of their own lives.

Additionally, some participants also discussed the need to communicate at an appropriate emotional level. This appeared to be more often the case for those speaking about subject material with health, societal or environmental ramifications, where there was potential for risk or harm. However, contrasting views of this were detected within interviewees' accounts: some felt that it was important to convey the significance, importance or urgency of the material, without displaying extremes of emotion that could ‘turn people off’. Others felt that in some circumstances, making a direct appeal to audience emotions could have a powerful effect and trigger important behaviour change. As Jeffries also stated:

You’re telling a story - and as with any good novelist, you've got to have a plot, you've got to have suspense and you mustn't give the game away right at the outset. You've got to hold things back. The other important thing... is to change the gear very unexpectedly. So I might be talking about some sort of ridiculous paternity case or whatever and then suddenly shift into a very serious rape-murder case. That keeps the audience on the hop as well. Because they don't know where it’s going and they don’t know - the emotional response takes a while to kick on: ‘oh God this is really serious stuff. I should be feeling serious and sad about this’. Or, ‘this is an extremely ridiculous situation that's just been described' and have a good laugh. So I think having that shift of emotional gear helps a lot as well.
Something that many participants appeared to agree on was the need to convey their personal passion for and interest in the subject material. As Bryan Gaensler succinctly put it:

You've got to be enthusiastic. If you're not enthusiastic why should they be?

Such comments suggest a desire for audiences to be emotionally engaged with the subject material, and there was in many accounts a strong sense of personal enjoyment and reward experienced as a result of feeling a rapport with audience members. Some participants appeared to experience strong feelings of reward from presenting not only as an authoritative expert but as one of them: a peer or equal, of similar status but sharing particular experience and knowledge.

Participants reported a variety of ways in which they endeavoured to connect with their audiences, including presenting familiar frames of reference and everyday examples that the audience could make sense of, showing that they were grounded in the same realities; using humour, to elicit positive feeling and demonstrate that they didn’t take themself too seriously; and revealing personal information and motivations or passion for their work, to demonstrate that they felt conviction in the subject material.

What is clear from these reports is that people use a variety of communication techniques and strategies to engage their audiences and that these are both consciously considered and carefully employed.

6.10 Personal communication techniques and strategies

One observation made of the interviewees was that almost all appeared to be excellent communicators; however from purely one-to-one conversations it was not possible to deduce what communication skills they might possess or draw upon when appearing before a wider audience. Therefore individuals were asked to describe some of the communication techniques and strategies they used
when communicating with others. The common themes arising from this line of questioning were as follows:

**The practice of presenting science**

Some reported that they would present subject material in such a way as to relate to the ‘ordinary person’s’ experience. For example, the astronomer Bryan Gaensler felt that he knew what level of knowledge and interest public audiences tended to have and the language they would understand, based on his repeat exposure to public audiences:

I was a tour guide at Sydney Observatory, which is part of Powerhouse Museum... and you turn up at the observatory once a week and you've got an RSL club or a bunch of scouts or just members of the public, and you just talk about the sky. And you can have everything thrown at you, because the telescope can break, you've talked up how amazing this particular star is and then the clouds come over, it can rain the whole night, you can have complete ratbags in your audience. So, after doing that once a week for four or five years, that was like boot camp, we can handle anything... whatever happens you just go with the flow, you also build up this whole repertory of answers and jokes and ways of handling the situation, it’s sort of like a giant database of every imaginable situation and how to deal with it, so that to me was really absolutely pivotal in everything I’ve done since. I actually give very similar technical conferences as I do to public talks, I mean they've got equations and text rather than pretty pictures, but I have the same approach in terms of the way of explaining things, and it all comes from talking to 8 year old cubs at Sydney Observatory.

Gaensler was unusual in having had so much experience interacting with public audiences from an early stage in his career; most participants reported gaining greater understanding of different audiences once they had achieved public exposure, bringing them into contact with a wider ‘fan base’ beyond their peers.
Indeed, based on the evidence of audience interactions presented in the preceding chapter, increased communication activity also increased awareness of audience sub-types and their differing communication needs, interests and experiences. Such knowledge appears to have enabled many participants to further shape the focus, style and content of their presentations.

Many participants talked about the importance of developing and improving their communication skills through practical experience. Some reported having had early, repeated practice in science communication through being part of specific communication environments that involved addressing audiences. Many participants commented on being members of groups where scientific ideas had been shared and debated. These included experiences at museums, observatories, planetaria and science clubs, or in youth organizations such as the Scouting movement or Gould League that encouraged an interest and achievement in some aspects of science.

Some of these experiences appeared to play a very significant role in engaging and developing the science interest of the participants; in one notable cluster, the astronomers Bryan Gaensler, Chris Lintott and Patrick Moore had all participated in amateur astronomy clubs, joining night talks and presenting their own findings to groups of interested others.

Others felt that they had started to practice essential communication skills as a result of being part of informal study groups, debating teams or theatre troupes; recollections of such environments suggested that people regularly performed or presented in front of a group and also had their performances critiqued and further developed through feedback from other group members.

**Planning a narrative structure**

For many participants, their communication efforts involved developing a structure for communication based around key points that would be prioritized for the audience to ‘take home’ or remember later. A number of participants
suggested that while the detail of their content could range broadly, it would usually be built around delivering a small number of key points – the fundamental ideas, issues or pieces of information that they really wanted the audience to understand and remember.

A coherent, well-structured narrative was considered by many to be important to the success of their communications. Some suggested that they used a ‘beginning, middle and end’ structure to first introduce their work, then detail particular elements of it, and then finish with a bigger picture.

Others reported using a central storyline that contextualised their work and led the audience through a series of interconnected steps. These would have a degree of flexibility in the detail, which could be changed in response to the audience reaction. Some participants reported that over time they had developed a wide range of content that could be swapped in or out, depending on the audience

Others discussed the importance of structure in creating a positive emotional experience for the audience. Some recalled using narrative structure to ‘end on a positive note’ and leave their audiences feeling positive or motivated to take action of some kind afterwards; in such cases, structure could be perceived as a way of manipulating or shaping people’s responses towards a particular outcome. Some participants, most notably environmental communicators, felt it was important to give audiences a sense of empowerment and ability to change; in one pertinent example Helen Caldicott said:

At some point I have to get them emotionally. So what I usually do is give lots and lots of information to establish my credibility as a scientist and as a doctor, so that I know what I'm talking about. And then towards the end I'll describe the horrific impacts of usually the nuclear situation, either power or war, or global warming. I'll go for where they really live, what things they really value in their life, what are they prepared to do to save the planet, not just for themselves but also for future generations. And if I can, at the end I'll find a baby and hold the baby up and say 'this is what
I’ve been talking about’ and then, often people lose it and cry. And then I’ve got them. I aim to change their life that night, so that they leave totally different...it often works.

Script development involved thinking about the narrative flow of the content, and planning how to tell the story. Some participants, having had previous success using particular types of communication aids, had almost formulaic ways of addressing script development – for example, they would ‘always’ use cartoons or tell jokes at the beginning to create a positive or humorous atmosphere and to put their audience at ease; or they would tell personal anecdotes to bring the story to life in ways that were person-oriented and engaging.

Some participants revealed a deep engagement with story telling techniques, of the sort that film makers might use – for example, citing their habit of building suspense and providing revelations, by creating twists and turns in their stories to reveal something that the audience did not know. Others, such as Ron Oxburgh described how he shaped his communication efforts to deliver both the aims of the presentation and the communication needs of the audience:

You basically just have to think through the narrative of what you're going to be saying and doing, you have to have a coherent picture in your mind...Then you've got a framework and then you build round it, depending on the reactions you get from the audience and so on, how you feel on the day.

Such accounts paint a picture of communication that is carefully crafted, designed to represent key themes but ultimately adapted and nuanced to suit the needs of the particular audience.

**Relevance**

Many of the participants cited relevance as an essential element to good storytelling about science, and when probed for more detail often equated it with
constructing or illustrating stories in such a way as to render the information more pertinent to the audience.

It was felt that relating stories at a personal level would enable people to emotionally engage with the content and feel rapport with the presenter. Relevance was achieved through a number of means including the use of language, vernacular or terminology most appropriate to the audience, the framing of content in ways that made sense to the existing interests or needs of the audience, through the use of metaphors and analogies that equated the complex processes of science with more familiar processes, and through the use of examples taken from the everyday realm.

**Non-verbal communication**

Many participants discussed their use of visual material to support their communication efforts and get their messages across. Photographs, cartoons and diagrams were all mentioned as useful aides to communication. One key observation was that the use of an appropriate visual mnemonic could convey critical information very quickly.

In one such example, Earth scientist Wally Broecker described how he had summarized his thoughts about the Earth’s ocean conveyor belt system, with a rough diagrammatic sketch drawn on a café napkin. Further development and refinement of the drawing eventually enabled a simple visual summary of the concept to be presented. Broecker recalled that after the diagram was published, the use of his ‘conveyor belt’ image became widespread and the image was rapidly appropriated (and also misappropriated) by many others; indeed his colleagues and students made a habit of collecting artefacts that contained the symbol, including bottles of drinking water. What started as a simple summary of complex science had evolved to become a marketing tool: a symbol for the water cycle and the purity and age of water extracted from the ground.
Examples of visual communication offered by participants did not just take the form of constructed graphics such as figures or diagrams, photographs or other sorts of printed imagery. There was also a sense of the embodied communication by individuals through personal styles of appearance, which for some individuals signalled a deliberate effort to make a point of difference. Examples of this included iconic garment choices, as in the case of Karl Kreuszeknicki and Adam Hart-Davis’ vibrant shirts, the accoutrements used by the Mythbusters’ such as Adam Savage’s dark-rimmed glasses and Jamie Hyneman’s black beret; and distinctive hairstyles such as that kept by Heinz Wolff, which conveyed his trademark ‘mad professor’ look. Such visible eccentricities had the appearance of being cultivated, and were largely observed amongst those with a strong television profile.

This observation makes sense in the context of television, which can be seen both as a highly competitive visual medium (Mee & Walker, 2014; n.a., 2012) and as a realm in which the tropes and archetypes of science play out (n.a. 2015c); thus both Wolff’s ‘dishevelled professor’ and Savage’s ‘chic geek’ can be seen as instantaneously signalling their scientific skills and knowledge.

**Translation**

A number of participants described their public communication as a form of translation, in which they took the technical ideas and terminology of their fields and re-presented them using relevant language, metaphors and analogies. Again, central to this process was an awareness of the audience, with many recounting experiences of engaging with different groups of people in different ways.

For some, it was a case of working out who would be in their audience, and thinking about how they would engage somebody ‘of that type’. Within many accounts there was a suggestion that individuals used the language that best suited the audience and presented information that was most useful to convey the concept, with a focus on placing it in a context that would have most meaning for the audience.
The use of stories.

Storytelling was explicitly mentioned by many as a key method for engaging with their audiences, regardless of that audience's domain expertise. As David Suzuki put it:

I don’t know how many speeches (I give) but it must be over 150 a year...I've got a huge accumulation of speeches. So basically what I am is a storyteller. I tell stories. Then I just pull them out and I write every speech I give out, longhand... But in the process of writing - I mean, I'm going to talk to a group in IT or a group of nurses, or a group of lawyers, and the message is basically the same but how you frame it to make it relevant to the audience is the important thing...because that's how you touch them. What I've certainly found is that people respond emotionally to stories. If you can relate the stories in some way, well, especially through children, that is what I tend to do now...

Suzuki’s account, similarly to that of Butler, highlights several key aspects of storytelling that were raised within the study. These included the use of short stories, which were often thought to be enjoyable and provide a ‘way in’ to the material for both the presenter and the audience. For the former, stories and anecdotes enabled the material to be presented in easily understood, easily delivered parts and provided a way of leading the audience through a broader narrative structure with over-arching themes or messages. Furthermore, presenters felt that stories were memorable, easy to recall and containing powerful ‘take home’ messages that could persist long after the communication had ended.

In this sense, short stories could be seen as offering simple and discrete ‘stepping stones’ along a more complex narrative pathway, each making its own salient point but also supporting the communication’s over-arching messages. They could also be seen as representing a constructivist approach to communicating
about science; each part of the communication scaffolding the next, enabling a greater understanding of the whole to emerge over time.

6.11 Discussion: The evidence for communication norms in science

From the accounts given at interview it was apparent that science heroes take a variety of approaches to communication and conceptualise it in a number of different ways. Unsurprisingly, individuals used strongly personal approaches, which developed from their own experiences and understanding of what was required or what worked within the communication contexts they experienced.

In some cases, the different approaches reported seemed somewhat oppositional; for example, whilst all participants clearly had specific communication goals, some spoke of communication strategies that were highly customized to the needs of the audience, whilst others revealed communication strategies geared towards maximum utility for the speaker. Some communication strategies were highly personable, apparently designed to build emotional rapport and minimise boundaries between the audience and presenter, whilst other strategies seemed designed to distinguish and elevate the presenter above the level of the audience. Some accounts suggested communication that was highly factual with a primary focus of communicating accurate scientific information to the audience, whilst others suggested that communication could be story-driven with a focus on conveying meaning and relevance, even if at the expense of absolute scientific accuracy.

These contrasting views and approaches suggest the presence of conflicting norms within science communication. Broadly categorized, these include conflicts between individual and collegial representations of science, generalization and precision, and dramatic and passive communication styles.
Individualistic versus collegial communication norms

Participants’ accounts suggested that their communication sometimes included personal recollections or anecdotes that positioned their own experiences centrally, in addition to information about the collective experience or body of knowledge, in which the individual’s role was less clear. Reasons for using personal anecdotes included to build rapport with or make the communication more interesting and relevant to the audience and to reinforce the positioning of oneself as a skilled and experienced authority or expert.

Such individualistic communication can be contrasted with collegial communication, which acknowledges the cumulative effort or collective knowledge of scientists and presents a rationale for scientific work in the context of the broader research field or research environment. Collegial communication positions the science clearly as work in which many individuals have a hand and based on a growing body of knowledge; it references major contributors in the field and acknowledges the primacy of other individuals.

Individualistic communication comes into conflict with collegial communication in part because it centralizes and preferences the knowledge and role of the individual above the work of others in the field; this is particularly problematic when the science being presented has been carried out by other individuals or as part of a group. The perceived disambiguation of scientific achievements from a collective endeavour to an individual one may signify that a claim is being staked to intellectual territory; in this context the act of ‘talking outside one’s area of expertise’ could be interpreted as an attack on the moral rights of those who have some claim to the work.

Collegial communication may come into conflict with personalised communication when it does not provide sufficient recognition for the contribution of the individual. Whilst scientific publications have clearly negotiated rules for acknowledging authorship, these are far less clear when it comes to presentations such as public lectures or other forms of communication.
such as media interviews. In these contexts, the work of a group is less visible and accessible to the audience than the personal experience and authority of the spokesperson; in the case of media appearances, the communication is also mediated through editorial processes and framing beyond the control of the presenter. Criticisms of ‘failing to acknowledge others’ do not take into account the fact that, in such scenarios, the risks and rewards of communicating are not distributed equally back to the college of science, but are borne disproportionately by the spokesperson.

This conflict helps to explain how individuals such as Sagan and Flannery can occupy such apparently contested territory in terms of opinion, where they are simultaneously acclaimed by their public audiences and criticised by their peers.

**Generalized versus precise communication norms**

Participants’ accounts suggested that their communication often utilizes generalization rather than precision to get the message across. Generalisations include the simplification of complex concepts into less complex derivatives, including visual representations such as diagrams; the use of metaphor and analogy; and the substitution of precise scientific terms or jargon for more commonly used terms.

Reasons for using generalisations included: to increase enjoyment and comprehension by the audience, and to achieve the aims of getting key messages or the big picture across, rather than communicating the detail. According to some accounts, generalisation and associated processes are necessary techniques to succinctly and rapidly communicate about science in time-constrained, non-expert environments such as those associated with the development of policy, in instances where specific actions are required of the audience, and in communication environments where audience attention is limited by the presence of competing communications, such as in television, radio, print and online media, and in live presentation environments such as public lectures. Under these conditions, generalization appears to facilitate clear communication.
and effectively places science in context, with a focus on the fundamentals and without the need for nuanced technical detail.

In contrast, precision requires the use of very specific language and nuanced terms that reflect the exact parameters of knowledge and outline any limiting factors, that inform about the specific processes underlying scientific claims, and that distinguish between findings obtained under different experimental or theoretical conditions. Such technical communication is a fundamental means by which scientists present their arguments with a view to establishing or asserting primacy. Under these conditions, individuals’ communication is competing not for the attention of the audience per se but for their agreement or, in some cases, their loyalty. Within research disciplines, it appears that scientists are swayed by precision, as it underpins the principle of repeatability. However as Collins and Pinch (1993) show, they are also influenced by rhetoric and other tactical communication methods aimed at convincingly asserting one’s own claims whilst undermining those of others.

Generalised communication comes into conflict with precise communication when it appears to omit details that are considered important within the discipline or creates the appearance of being factually wrong. This is the case where terms with broad social meaning are used preferentially to those that have a high degree of scientific accuracy. For example, use of the term ‘bugs’ in a presentation might equally be understood, in the public domain, as meaning insects, infections, software failure or surveillance equipment and the particular setting for its use would enable the audience to know exactly which meaning of the term ought to apply. In the scientific domain, generalized terms have limited utility; it is the precise use of terminology that signifies both key information and the context and intent of the communication. Thus ‘bugs’ has no real meaning except in the context of a particular class of insects, and treatment of infection cannot proceed until ‘bugs’ are re-defined as a particular strain of bacteria.

Precise communication comes into conflict with generalized communication when it eschews the broader context or fails to connect the scientific detail with
the question of ‘so what?’ . This is a particular problem when communicating in a public policy environment, where both precise and generalized communication are required in order to adequately engage audiences with different levels of understanding and those tasked with responding to societal and political as well as technical considerations. The communication experiences of scientific advisors such as Harry Butler and Ian Lowe can be understood through the lens of conflict between these competing norms; when their major audience is not a technical one requiring precise scientific knowledge, but a public one with keen interest in the outcomes and meaning of their work, generalisations are required. Of course, these generalisations do not present all of the detail – but they do enable the bigger picture to emerge and the reasons and rationale for the work to become clearer to a non-technical audience.

Thus generalization and precision are revealed as a competing pair of norms, which are used within different communication environments. While generalization seems not just desirable but necessary within a public communication environment, it has limited utility within scientific information-sharing environments, where precision is essential.

**Dramatic versus passive communication norms**

Participants’ accounts suggested that they use narrative devices or storytelling techniques to convey their messages, applying structural elements of drama such as rising action, suspense, ‘twists and turns’ or sudden changes in the narrative. Dramatic structures clearly aim to elicit emotional or sensory responses from an audience, and are supported in a variety of ways including through the design of pace and timing, the inclusion of personal information about the individuals involved and the use of visual and audio elements designed to induce an emotional response from the audience.

Reasons for using drama include: creating personal interest and meaning for the audience, communicating the passion and vision behind the work, conveying the difficulties or obstacles in the work, and revealing insights or ideas in a way that
compellingly conveys their significance or importance. It may also place the individual in the central role of narrator – a position signifying not only that they are in possession of expert knowledge but that they have the authority to speak about it. Dramatic communication contextualizes the science as being current and important, and positions the communicator as central to the action. The audience, through their proximity to the presenter, comes to occupy a privileged position close to the heart of the action. Dramatic communication facilitates emotional responses and open-ended interpretations of meaning; the data suggests that it can foster a positive relationship between the audience and presenter, building bonds of trust, love, compassion, admiration and gratitude as evidenced by the behaviours displayed towards science heroes by their fans.

In contrast, passive communication omits descriptions of human factors or motivations and implies a detachment from the scientific work on the part of the presenter. Interpretations of its meaning are mediated through the presenter, creating a sense of distance. Passive communication describes the technical reasons for carrying out the work and summarises rather than explores its importance. The language used in passive communication signifies detachment; for example, third-person statements may be preferred above ‘I’ statements. The politics underlying decision-making relating to the work may be downplayed or omitted altogether, and contributors and stakeholders to the work are acknowledged equally dispassionately. Passive communication is useful in many technical communication contexts, when the outcomes of scientific work are the main focus and audiences have a focus on obtaining practical information.

Dramatic communication comes into conflict with passive communication when it appears to preference the emotional or material motivation of individuals over the intellectual reasons for the work, to overstate the importance or meaning of problems with science or to present an emotional context for scientific work that differs from the experience of those acquainted with it. Thus dramatic communication may lead to criticisms of ‘exaggerating the claim’, being inaccurate or biased, or ‘not telling the full story’. However, dramatic communication is also an important signifier of the emotional and human
experiences of science, and its meaning for society; it acknowledges the presence of human behavioural factors, helps explain the motives for how and why science is progressing and describes the interactions between key stakeholders who include not only those who are involved directly in carrying out research but others who may be dependent on, interested in or impacted by it.

Passive communication comes into conflict with dramatic communication when it denies the involvement of emotional or material motivations on the part of individuals and portrays science as a practice abstracted from the normal realms of human emotional experience. This portrayal is at odds with actual human experience and thus may lead to problems such as mistrust of science, where individuals presenting science are perceived as manipulating or hiding important information, and accusations that science is dangerous, boring or ‘pointless’. Passive communication may present greater levels of detail, provide required technical clarity and have utility for particular audiences, but its experiential value is very limited; in contrast, dramatic communication excites, warns or inspires, by selective representation of the material and deliberate construction of experiential journeys.

6.12 Chapter summary

This chapter aimed to explore the communication experiences and characteristics of science heroes. Within their accounts, a number of common communication issues were identified, which further analysis suggested was indicative of the presence of competing communication norms.

The detection of conflicting communication norms lends itself to several conclusions. First, that communicating science effectively offers significant challenges for the presenter, who must find a balance between communicating for their own needs and for those of their audience. Second, audience receptivity and communication needs appear to vary within technical and non-technical communication settings, and these require different communication approaches to be employed. Third, the communication techniques that may be most
appreciated by and effective when communicating with a non-technical audience conflict with those required for a technical audience, and vice versa.

These issues are problematic for individuals whose communication activities straddle the boundaries between technical and non-technical worlds; their communication does not exist in isolation, but is available to be critiqued by anybody who encounters it. Difficulties arise when audiences intersect; for example, a television appearance designed for a non-technical audience, using generalization, passion and humour for maximum effect, will also be encountered by technical specialists with an interest in the subject matter to whom its personal, generalized and dramatic form may be provocative. Likewise the passive, specific and collegial forms of communication that are both anticipated and effective within technical information-sharing environments have very limited utility beyond it; non-technical audiences cannot easily translate the detailed terminology and complex concepts of the expert to develop a meaningful understanding of the content.

It appears to take great skill to successfully navigate these competing norms to simultaneously maintain a popular non-technical and a well-respected technical communication presence. The concept of competing communication norms helps to explain the dichotomous views on and reported treatment of some individuals within the study, which showed that even much-loved science heroes come in for their share of criticism, whether from the non-technical audience who may feel the communication is too dry or inaccessible when it should be entertaining and understandable, or from the technical audience who feel it is too simplistic, personal, emotional and inaccurate, when it should be detailed, detached, objective and highly accurate.

One might interpret this schism as a failure on both sides to grasp the fundamentally different communication needs of different audiences; in fact, in order to succeed within science and society individuals must necessarily learn the skills to navigate both. And indeed, within the study cohort most individuals appeared able to successfully navigate their way between these competing norms.
Chapter 7: Discussion and Conclusions

The shock comes because the idea of science is so enmeshed in philosophical analyses, in myths, in theories, in hagiography, in smugness, in heroism, in superstition, in fear and, most important, in perfect hindsight that what actually happens has never been told outside of a small circle. Collins and Pinch (1993, p.2)

7.1 Chapter overview

This chapter reviews the findings of the research as presented in the preceding chapters, presents the conclusions and implications of the study, and makes recommendations for further research.

7.2 Answers to the research questions

The study set out to address several key research questions: What experiences characterize the science pathways of science heroes and what role do ‘inspirational others’ play? What are the communication characteristics of science heroes, and what can these characteristics tell us about the heroic archetypes of science? Last, how do the norms of science and heroic storytelling intersect, and what consequences do these have for those individuals singled out as science heroes?

Arriving at succinct answers to these questions was no easy task, given the richness and complexity of data originating from almost one hundred interviews, with individuals whose interests, experience and journeys in science were hugely diverse. Their stories, both extraordinary and mundane, revealed many recurring themes relating to inspiration, communication and success. Yet these accounts were also often contradictory, with contrasting views of how science should be communicated and to whom. In the following sections, I briefly outline and discuss the major themes as they emerged from the research.
7.3 Emergent themes: Experiences characterizing the pathways of science heroes

The data presented at interview revealed a staggering array of experiences that contribute to individual science pathways. Family cultures and expectations, the availability of support, encouragement and guidance from parents, teachers and mentors, stories about science heroes and scientific processes explored through literature and popular media such as film and television, self-guided or social experiences with toys, museums, clubs, and science fairs, play, discovery, observation and experimentation in the natural or built environment, underlying aptitudes, skills and interests, explicit direction from others, intrinsic ideas of self and group identity, and modelling on near or distant role models were all revealed as having had significance to many different people. The pathways that these individuals took all differed, occurring as they did from diverse and variable bases of personal opportunity, exposure, interest, education, inspiration, and experience. These findings tally with those of researchers such as Cleaves (2005) who has highlighted the wide range of factors influencing the formation of science choices.

It was also apparent that deeper engagement with science can and does occur at almost any age. Whilst strong motivations to explore science pathways and pursue science-based careers were commonly experienced in childhood and adolescence, reinforcing notions that science engagement programs are most effective for these age groups, many participants reported that their use of scientific knowledge systems and development of pathways into science also occurred much later in life, often motivated by a personal or professional need to understand, draw on or apply scientific knowledge. The availability of both scientists and non-scientists as a locus for information, inspiration or advice about science also appeared to be important, with impacts felt at all ages.

The results implied a crystallising sense of science self-identity in individuals, developing over time and informed by experiences of what was personally interesting, enjoyable, thrilling, important, desirable and/or valuable. Extrinsic
motivators, such as positive reinforcement, intrinsic factors such as curiosity and natural aptitude, and life experiences all appeared to play some part in the desire of individuals to seek further engagement in science. Within the interview cohort, many individuals referenced strong family and community environments that enabled and supported a clear sense of identity, interest and achievement in science. This finding tallies with that of researchers who have recognised that an individual's life experiences within out-of-school settings, yield knowledge that is useful, powerful and transferable. For example, Basu and Barton (2007) found that: ‘when students...could choose and engage in activities connected with their visions of the future, how they valued relationships, and their definitions of science, they developed a strong, long-term commitment to pursuing science’ (p. 487). Certainly, the importance of individual visions for the future rings true in this study.

The data suggested that for science heroes, the development of strong and robust self-identities in science formed over time under the influence of many different factors. However it was also clear that a sense of engagement with or desire for ‘more science’ could also be accelerated by key experiences. Specific ‘first-time’ events, such as using a real telescope, witnessing the explosive power of a chemistry set, doing well in a competition or encountering a powerful story about science, told by or depicting a charismatic individual, were all reported as having dramatically increased individuals' sense of engagement. This finding is suggestive of the accelerated responsiveness to external experiences that is thought to happen during ‘sensitive periods’ of childhood development, which Leites (1996) defines as specific, selective and heightened responsiveness to everything going on around a child. According to L. V. Shavinina (2013), such sensitivity provides favourable conditions for accelerated intellectual development, which she argues is critical to the development of scientific innovator-geniiuses.

However, it was clear that the participants in the study were not only those who considered themselves ‘naturally gifted’ in science; for some, despite having an enduring curiosity and some early interest in science, the journey into the world
of science was a long and laborious process, which arose predominantly from the weight of others’ expectations or through serendipitous circumstances, rather than by any particular design. Indeed, several participants recalled ‘drifting’ into a science stream or not being particularly ‘good’ at science academically until gaining interest at university or in their later years. Some were even labelled as ‘low-capability’ individuals in their childhood years, based on behavioural difficulties, flawed IQ testing or the negative opinion of teachers, only discovering later that the opposite was the case. Yet despite this, such individuals stayed the course, highlighting the personal traits of strong self-belief and persistence that were common to many participants. The strength of their intrinsic interests, experiences of positive, co-incidental reinforcement and plain good luck all appeared to have played an important role in their eventual journeys to success.

In most cases the individual experiences of science in childhood arising outside formal learning environments or schools were distinguished qualitatively from those experienced within. For example, many participants described solo experiences of science, particularly in adolescence and often in the natural world, which played a crucial role in the formation of their sense of self and confidence in their intrinsic interests. These experiences were frequently strengthened and extended within the family context, however, or through social reinforcement. For some, the seclusion and confusion of adolescence was alleviated by immersion in favoured recreational science hobbies or pursuits; many individuals took comfort in experiences such as inventing or making things work, or in exploring the living world around them through play in nature parks and wilderness, in which they made their own observations and formed questions for further investigation. For others, science was a very sociable pursuit, a hobby or an experiential and educational realm shared with others, in which important friendships and social identities developed.

However, when the balance of evidence was considered it seemed clear that lived experiences informed scholastic pathways and vice versa, reminiscent of the ‘third space’ between the cultural worlds of school and the community that is
thought to bring together privileged content and discourse from other content areas (Moje et al., 2004). This effect was particularly apparent when individuals felt supported by the attitudes, information and opportunities provided by adults in their lives. Positive reinforcement for participants came from many different sources. Most individuals reported being encouraged by experienced and supportive elders including parents, teachers, academic mentors and role models, whose tacit support or direct intervention helped to nurture, guide, shape and inform their interests and pathways in science. While the study could not explore the full impact made by any one of the individuals mentioned at interview, anecdotal evidence suggested that a single, very effective teacher or role model could have a profound effect on the attitudes and interests of substantial numbers of individuals within a generation. Yet, whilst for some a particular teacher’s influence was a driving factor in their future interest, for others, teachers presented just one more part in a chain of many interlinked and cumulative experiences. Skilled and charismatic supervisors leading clusters of superb scientific talent were commonly experienced, but there was a sense that ultimately individuals would strive for more; in many cases the aspirational heights modelled by science heroes would be at least matched, if not outstripped, by their protégées.

From all the evidence collected, it appears that it is the unique combination of interests and experience, opportunities and support, inspiration and ambition, talents and touch-points that shape pathways into science. No two people are the same, although they may have experiences that similarly accelerate, inspire or train them. Certainly, science heroes are a crucial contributor to the mix of influences to which people attribute an interest in science – and having access to a wider circle of inspirational individuals is essential to scaffolding not just individual engagement but collective success, by forming the nucleus of lineages that extend across and between scientific generations. Nevertheless, science heroes must be seen as just one relational element in an individual’s complex experience of and attitudes towards science. This finding suggests that any approach to accelerate individuals’ pathways into science through the
constructed use of mentors or ‘inspirational others’ should carefully consider how these intersect with, lead into and build upon other experiences.

What experiences characterize the science pathways of science heroes and what role do ‘inspirational others’ play? In summary, a huge variety of influences affect individual pathways into science and important motivational elements can be experienced at any career stage. Inspirational individuals are a particularly important subset of these, with this study providing a clear indication of the powerful effects that mentors can have - not just through inspiring interest and encouraging deeper engagement but by transferring critical knowledge, skills and connections to others at almost every stage of one’s career. It is apparent that, when it comes to inspiring others, it is never too late to have an effect.

7.4 Emergent themes: How science norms intersect with storytelling about science

The research investigated the communication experiences and characteristics of science heroes and considered them in light of the norms and competing counter-norms of science, such as those proposed by scholars including Merton (1957). It was also noted that whilst scholars have observed differing communication characteristics amongst science heroes, to the extent that some such as Pinch (1992) have offered a loose typology, those characteristics have not previously been examined in detail. The exploration offered by this research provided new insight into the prevailing norms of science, which strongly suggested the presence of previously unrecognized communication norms inextricably woven into the processes, practices and communities of science. Like behavioural norms, those relating to communication appeared dichotomous; three major pairs of communication norms and competing counter-norms were identified, which can be categorized as personal versus collegial, generalized versus precise and emotional versus passive.

Applying the lens of such competing norms made sense of both previous suggestions within the literature (Wellcome Trust & OST, 2000; Davies, 2008)
and accounts given at interview suggesting the existence of significant conflicts around communication, within this study exemplified by the experiences of Tim Flannery, Johnny Ball and others. Apparent problems of divulgation and widespread reports of professional consequences for those ‘talking out of turn’, such as jealousy, criticism for being a showman or charlatan, professional undermining, stymied publication, and personal or public vilification could all be seen as expressions of the conflict. Whilst these consequences were clearly costly, they did not appear to outweigh the benefits that many people felt flowed from embracing communication. Indeed, most participants felt a strong sense of responsibility to communicate, describing it as an obvious requirement for successfully attracting and acquitting public support for science. Many also expressed a sense of obligation to their audiences and profound enjoyment in communicating well, describing the techniques used in reaching out to engage others. These included storytelling and the creation of distinct narratives about their work, using highly relational forms of communication such as social or person-centred examples and extended discussion or question-and-answer formats, accessible language rather than jargon and the use of other communication elements to aid effective communication such as metaphor, analogy, humour and visual imagery.

Nevertheless these did not appear to be communication skillsets that were easily or widely replicated, and many participants observed the co-existence of 'careful, meticulous and detailed' communication styles that favoured scientific accuracy, involving abstraction and qualification of detail, contrasting those favouring context and impact, which involved the condensing and/or generalisation of scientific facts in order to increase relevance and make linkages between them. The ability to utilize these different skillsets in different contexts was considered important, although many participants observed that this was frequently difficult for individuals other than themselves.

As judged by their performance at interview, whilst most participants could be considered naturally gifted communicators, many reported working with those who ‘never would be’ naturally inclined to communicate; and, whilst the constant
rehearsal and refinement of communication skills was a trait common to many in the interview cohort, at one extreme were those who performed ‘off the cuff’, improvising almost everything based on inter-related short stories and dynamic flow and at the other those who laboured under more formulaic approaches, carefully scripting each encounter. Whilst the latter group appeared to have more concern about accuracy, in both cases key consideration was given to what audiences would find relevant, interesting and inspiring.

For those with fewer supporting resources at their disposal, and less experience of managing different stakeholders with varying communication needs, the likelihood of transgressing one set of norms or another appears to be quite high. The criticisms levied at high profile individuals when they ‘get it wrong’ supports this supposition; it appears that one can rarely satisfy every audience, particularly when those audiences have wildly different communication needs. Therefore, studies of science communication should take into account the variability between individual communication preferences and skills, with sensitivity to how these may vary over time and with different degrees of experience and training. Furthermore, they should recognise the inherent potential for conflict between individuals approaching science communication from different perspectives and with differing motivations, which may play out covertly and overtly through criticism, obstructionism and dismissal.

What are the communication characteristics of science heroes, and what can these characteristics tell us about the heroic archetypes of science? In summary, science heroes use a variety of techniques to engage their audiences, which frequently transcend well-understood communication modes such as the ‘deficit’ model. Typically, science heroes respond to their audiences in positive and nuanced ways with sensitivity to differing knowledge bases and levels of understanding. They are frequently adept at translating science to meet the informational needs of their audiences, in many cases using narrative approaches to contextualise and scaffold key concepts. And in the process of telling stories about science, they utilise archetypes that portray science as fascinating, exciting, dramatic and stimulating, as a process of enquiry creating a reliable knowledge
base and as a social undertaking with benefits for society. Whilst these archetypes were identified from a relatively small cohort of individuals, their presence raises fascinating possibilities for further investigation.

7.5 Emergent themes: Communication as a source of conflict

*If I have seen further it is by standing on ye sholders of giants. Isaac Newton, to Robert Hooke (1676)*

The tension between Newton and Hooke, scientific superstars and rivals in their day, is a matter of historical record. Like many other great clashes between intellectual foes, it was characterized by bitter acrimony, particularly over primacy. Hooke, a polymath and brilliant experimentalist, claimed that Newton’s publication of *Principia Mathematica* failed to acknowledge Hooke’s prior work; Newton, a brilliant theorist and mathematician, provided detailed proofs that he believed stood independently of Hooke’s work. Ravaged by a war of words and barely civil acts of contrition, the relationship soured. While Hooke’s reputation languished, history would celebrate Newton as the most influential scientist of the 17th Century n.a. (2016).

Scholars such as Collins and Pinch (1993); (Kuhn, 1962), Kuhn (1962) and Merton (1957) have argued that the history of science is littered with such conflicts, and that these are driven by sociological norms within science. Certainly, the interview data provides some insight into the social norms that prevail within research institutions. While individuals also have their own personal value frames that inform how they respond to the world, many elements of which were visible at interview, the value frames that relate to the norms of science were also apparent within their accounts.

As noted in earlier chapters, a number of participants expressed outrage at perceived wrongs done to colleagues by others within the scientific elite. In one case, this outrage was caused by colleagues delaying a review of an important publication until they could publish their own results, thereby undermining their
competitor’s claims to primacy. That there should be evidence of this within the study is unsurprising; according to Merton (1957) controversies over who has primacy for a new discovery are relatively common. Scientists’ claims, made through publication of crucial theories and supporting evidence, may easily be obstructed or delayed by others involved in the publication process, and individuals may have their claims sullied by accusations of dirty tricks, such as failing to attribute ideas generated by others or deliberately stalling the publication of important results, in order to write up and publish one’s own.

At times such conflicts can be negotiated to everybody’s satisfaction, as was historically the case with Charles Darwin and Alfred Russell Wallace, whose work informed one another’s and who avoided open conflict by jointly publishing their initial ideas about evolution in 1858. Similarly, the rival researchers Watson and Crick (at the Cavendish Laboratory, Cambridge) and Wilkins and Franklin (at Kings College, London) shared their findings regarding the structure of DNA in claims jointly published in the journal Science in 1953; the co-publication experience reported by Gerry Wasserburg carried overtones that suggested a similar collegiality. Nevertheless as the historical example of Newton and Hooke shows, when the stakes are high and pride is one of the things at stake, bitter rivalry may escalate until there is but one outright winner. Certainly, the contested nature of Flannery’s public presence and communication efforts suggests a degree of rivalry, reminiscent of what Fahy (2012) describes as ‘a tension between public profile and scientific status’ (p.297).

Nevertheless, the majority of accounts provided by participants in this study strongly suggested that science in the early part of the 21st Century is increasingly collegial, multi-disciplinary, globalized and also communicative, and that in this environment interpersonal skills are critical to success. When it comes to forming or leading a research laboratory, influencing policy-makers, teaching or mentoring students, explaining emerging issues or galvanizing change within society, there was a strong sense that skilled communicators may increasingly have the upper hand. Whilst conflicts over the nature, content and intent of communication rage within science, triggered by clashing norms and the fact
that scientists may be divided on many issues (Hilgartner, 1990), in the public
domain there is little contest. As accounts by those such as Jeffries, Sykes and
Attenborough show, to be known is to be trusted – and to be trusted is to wield
influence, socially, politically and, ultimately also scientifically.

7.6 Emergent themes: Communication and the heroic
archetypes of science

As discussed in Chapter 2, heroic archetypes of science abound as evidenced by
the proliferation of tropes such as those seen on television and in cinemas.
Fictional characters aside, few scholars besides Pinch (1992) have previously
attempted to categorise the heroes of science according to their communication
characteristics, and as has been shown here, these characteristics can be further
understood from a perspective of competing communication norms and counter-
norms.

It was apparent from this research that science heroes embody many different
aspects and representations of science achievement, including indisputable
demagogues of intellectual prowess and primacy, as demonstrated by those
ascending to the ranks of the Nobel Laureates, demonstrators of compassion and
humanity, such as those embodied by the medical professionals preventing
illness, repairing trauma and saving lives, and interpreters or translators of
knowledge, as exemplified by those working in the realms of popular culture and
entertainment media. Interpretation of their accounts of communication
suggested the presence of several distinct depictions of science: as a process of
enquiry creating a reliable, comprehensive knowledge base about the world, as a
social undertaking, with benefits for society and as a fascinating, exciting,
dramatic and stimulating practice. Such narrative devices appear to be employed
consciously and thoughtfully as part of individuals’ storytelling about science,
and frequently with clear intent to engage audiences emotionally. This
intentionality may add a new dimension to explorations of celebrity and science,
such as those by Fahy (2012) who has suggested that scientists’ public image is
primarily constructed around discourses of truth, rationality and reason. This
study suggests that the relationship between science heroes and the public is far more complex than this, with trust and inspiration also appearing as potential drivers within the reported correspondence from audiences.

Such storytelling motifs also echoed the narrative themes recalled by participants as having characterised the literature, popular media and relational experiences that had been of significance to them in earlier years. This observation gives rise to a sense of narratives repeating over time as part of both individual science understanding and identity formation and the broader discourse about science. That such stories appear to resonate and recur over time raises intriguing possibilities for further studies of the ‘collective unconscious’ in science and the means by which archetypes, such as those suggested by Campbell (1949), persist and are passed between generations, through the formal and informal communication efforts of individuals.

It is also clear – and perhaps unsurprising – that the communication behaviours, conflicts and norms summarised above appear to be intrinsically interwoven, to the extent that they cannot be easily separated from one another and concise answers are difficult to arrive at. It is therefore useful to highlight some of the further problems in science communication identified from this research.

### 7.7 Further problems in science communication

In summary, the accounts given at interview identified a number of issues experienced in relation to the communication of science, best summarised as follows:

_Tensions between scientists and the audience, arising from different understandings and experience of the subject matter and also from differing comprehensions, motives and demands when participating in the communication._

It was clear that one-way models of communication, such as the so-called deficit model, belie the truth of how spokespeople for science are viewed; far from being passive consumers of the messages that scientists and scientific enterprises may
wish to be taken, audiences bring their own agendas, understandings, informational needs and relational ideals to the equation. The call by participants such as Grant for ‘more listening’ and Coggins for ‘more questioning’ are supported by warnings from those within the broadcast and entertainment industries that things have changed – top-down imposition of communication agendas is failing in a world where consumers can go elsewhere for their information.

_Tensions between scientists and ‘the media’, which derive from a conflict between the media’s own needs and agendas and its role as an intermediary between scientists and their audience._ It was clear that many in the study experienced a mixed relationship with the media, in many cases feeling ‘burned’ by it when stories about their work or their field did not reflect the reality as they experienced it, or when their efforts to communicate were truncated, leading to altered meanings. In some cases there seemed to be misunderstanding about the role of the media in relation to science, with people often seeing the media as creating a story where there wasn't one, fabricating and then taking the ‘wrong side’ in a debate or undermining certain communication values such as accuracy, collegiality and impartiality. More nuanced views of these problems emerged from those with a great deal of media experience and training; for example, individuals such as Marshall, Jeffries and Fraser adroitly managed potential tensions, by shaping their communication in ways that would ensure their own objectives could be met.

_Tensions between scientists over issues of accuracy, recognition and domain expertise, usually arising from the processes of generalization used in order to create meaning for the audience._ It was clear that such conflicts were reasonably common, highlighting the potential presence of competing communication norms and the perfectly natural desire to have one’s own expertise, knowledge and achievement recognised. Whilst in some cases conflict was exacerbated by the processes of mediating information, such as those used by editors to create more succinct and engaging copy, in others it was exacerbated by misunderstandings about the communication setting or context. For Winston or
Attenborough, tasked in their respective programs with condensing knowledge from vast disciplines such as reproductive medicine and zoology, the tensions seem particularly clear. Much loved by public audiences who see them as giants of and gateways to their fields, they must work hard to bring their scientific colleagues with them; a case, perhaps, of one expert’s appropriate simplification being another’s distortion (Hilgartner, 1990).

All three of these problems bring enormous communication challenges to those who represent science in the public domain and who try to successfully forge a path towards the inspiration of others. In the articulation of these lies the hope that solutions will be found, to support and encourage the development of communication skills that serve the needs of both science and the public.

How do the norms of science and heroic storytelling intersect, and what consequences do these have for those individuals singled out as science heroes? In summary, the norms of science include several pairs of dichotomous and competing communication norms, which act as a potent source of conflict within scientific communities of practice when individuals approach communication from vastly different perspectives. These issues are particularly problematic for those whose communication activities straddle both the technical and non-technical worlds and when audiences for their communication intersect, as is the case when communication is broadcast or published in non-specialist locations. Under these circumstances, the individualistic, generalised and/or dramatic communication approaches used to good effect when conveying the value, importance and significance of science may conflict with collegial, precise and/or passive communication norms, which appear to underpin much technical communication about science.

Within the dynamic communication environments of today’s workplaces and public venues, it seems clear that even the most adept communicator may fall foul of these norms. For individuals singled out as science heroes, in the process of engaging non-technical audiences the challenge is to first understand how, where and why such conflict arises, and then master the art of engaging others in
nuanced ways that minimise the opportunities for criticism by their peers. Nevertheless, whilst some severe consequences undoubtedly arise from contravening these norms, the benefits for individuals of contributing in both scientific and non-scientific spheres are substantial – and increasingly, fundamental to the practice of science in a globalised world.

These findings have implications for how science communities understand and respond to communication opportunities, for the training required to equip individuals with sufficiently nuanced and effective communication skills to survive and thrive in their careers, and for the studies of science that seek to understand how scientific and popular cultures intersect.

7.8 Limitations of the study

This was a qualitative study with a carefully designed methodology as described in Chapter 3. Quantitative analysis was not considered appropriate for the data gathered, as according to Gibbs (2007) that requires homogenous populations that can be easily compared, enabling generalized, aggregate statements to be made that are consistent with the information provided at individual level. In this case, it was clear from the outset that despite some cultural similarities, the range of ages, life experiences and STEM fields represented within the sample population meant it was likely to be non-homogenous. It was also anticipated that, while some interviewees might share experiences in common, most participants would have unique combinations of experiences to report.

In this study the nature of the relationship between science heroes and their audiences was viewed only from the perspective of interviewees, based on reported correspondence and interactions and, rarely, on direct observation of fan behaviour. Whilst this approach yielded much useful information, it constitutes an obvious limitation of the study in that the nature of these relationships remains unknown from the perspective of the audience. Verification of the relational elements identified in this study would require
further investigation with a wider population, using a combination of both qualitative and quantitative research techniques.

A further limitation of this study was the inevitable selectivity required for succinct reporting of the data, which necessarily meant that the vast majority of detail contained within individual accounts remains concealed. Indeed, one frustration caused by the breadth and complexity of data was that the true diversity of lived experiences could not be shared, and in some cases ethical considerations prevented such information from being attributed and in occasional circumstances, not cited at all. Such omissions were made in line with the ‘do no harm’ principle for designing and reporting on qualitative research, such as those described by Flick (2007) and Kvale (2007). However, the examples provided within the text must be viewed as just the tip of a very large iceberg – some of the specific conflicts and communication experiences reported very briefly in the study are far more complex than described here and are certainly worthy of further examination in their own right.

In addition, as the entire transcript provided at Appendix 6 show, the full range of each science heroes’ experiences, observations and opinions contained many nuances and ideas worthy of further investigation. Despite best efforts to analyse and interpret the data as it related to the research questions, inevitably important points were raised that sat just beyond the boundaries of the study’s main focus. The unexpected breadth of the issues identified also prevented detailed exploration within the narrow confines of the required word limit. Inevitably much potentially useful information was not explored, forming the basis for further research as outlined in the recommendations below.

7.9 Concluding statement

The volume of data gathered during this study constitutes a rich data set that is relevant to both sociologists of science and scholars in communication fields. Whilst this is the first study to draw on the data set it should not be the last, with many of the issues raised warranting more in-depth examination. To enable the
claims made within the study to be tested and the findings robustly reviewed by other scholars, the underlying data should in due course be published or made available to other researchers, subject to participant permission.

This study has shown that science heroes are a subjective phenomenon, whose importance is both individually and socially constructed, and whose impacts can be far-reaching, intergenerational and highly motivating to others over time. Programs that seek to use science heroes as a mechanism for increasing public or educational engagement with science should account for these effects within the program design. For example, a sporadic, ‘one-off’ or ‘one size fits all’ approach should be discarded in favour of or at the very least be well-supported by more nuanced and personalised approaches, that recognise the importance of relationships between individuals and those who can inspire and nurture their interest, and that prioritise individual experiences and the nurturing of self-identity in science.

At the level of society science heroes are powerfully useful – their achievements and failures form potent narratives to entertain, delight, confound and inspire us; meanwhile they can simultaneously inform and have impacts in political, economic, educational, spiritual and societal spheres. Such impacts are largely informed by individuals’ communication skills and personal awareness of audience needs, and it is apparent that for the most part, individuals use their skills to good effect. However, the development of individual communication skills also appears to be ad-hoc, built on a foundation of personal traits and practical experience that varies significantly between individuals. The experiences reported at interview strongly suggested that many important communication skills, including managing and working with the media, are learned on-the job rather than being a standard part of professional training. For those thrust into the limelight suddenly, the experience can be both overwhelming and bruising. A strong case therefore exists for training programs that support science communication skills development, and that enable individuals to gain knowledge of and formulate effective and flexible strategies for communicating in a wide range of environments.
The study also suggests that communication norms are present within science, that these are just as contradictory as its behavioural norms, and that significant negative consequences exist for those perceived as contravening these norms. In addition, whilst there are many societal, personal and professional benefits for those who engage in public communication, this too can have substantial negative consequences for the individual. Whilst this study did not examine specific strategies used by individuals to navigate these norms, it would be another fruitful area for researchers exploring the sociology of science and popular representations of scientists.

The results suggest that the presence of science heroes has diverse utility at many levels of society including within institutions, where it is apparent that they can represent a visible standard of excellence and embody achievement, whilst also becoming a potent contributor to cultural change within the organisation due to their public influence and ability to attract new cohorts. Above all, they may act as a driving force in their particular communities of practice, becoming a beacon to those seeking success in scientific careers.

Their impacts are not felt just in fields of scientific or technological endeavour but also in much wider cultural and social realms. The interviews gathered here suggest that science heroes are constructed and valued within society at both a collective and an individual level; whilst their popular appeal may be pervasive and enduring, as in the case of those celebrated through literature, television and other popular cultural channels, their influence and importance can be seen as highly subjective and constructed according to the needs and experiences of the individuals who behold them. At this level, science heroes can and do play many different roles. To some they may act as teachers or mentors, to others they model exemplar behaviours or ideologies, and yet to others still, they may represent aspirational goals or define required performance benchmarks. They may be located close to the individual or distant from them, have a force of impact derived from repeated or rare contact and influence others through technical or social achievement. In short their utility is multi-faceted and diverse, as exemplified by the myriad subjective human experiences reported here.
Nevertheless one particular value shines through that is worthy of further consideration. In engaging with their science heroes, it appears that many people seek answers to those critical questions so embodied within the practice of science; those of why, how and what? As the correspondence reported by science heroes shows, many individuals possess great curiosity and in seeking contact can be seen as actively pursuing scientific knowledge and conversations about it. As this study shows, when that conversation is engaged in and sustained, individual self-identity may be greatly nurtured.

In returning to the question asked by Lindsay Tanner regarding the inspirational impact of that ‘flamboyant professor’, Julius Sumner Miller, we may see that there is at least a partial answer – whilst celebrity undoubtedly has its own value, as described by scholars such as DeWitt (2006) and Fahy (2012), beneath the media buzz of the public scientist is a real person, whom aspirational others can and do seek out for direction and guidance. These storytellers of science are also facilitators of engagement, trusted guides to deeper knowledge and modellers of key behaviours. As such, their iterative, interpersonal impacts may perhaps be just as important as their scientific, technological or environmental achievements. For ultimately, such individuals become those ‘giants’ on whose shoulders future generations may stand.

**7.10 Major recommendations**

1. Recognising the important role that ‘influential others’ play in helping individuals to discover and follow pathways into science, organisations seeking to inspire a new generation of scientists through the construction or use of ‘science heroes’ should give consideration to the communication skills and attributes that individuals may require to excel in that role. In designing such programs, consideration should be given as to how inspirational experiences may be interlinked and deepened, with the aim of creating experiences that both excite the imagination and enable ongoing interpersonal relationships to develop.
2. Recognising the individualistic and highly personalised nature of pathways into science, storytelling about science should aim to create positive visions of the future for individuals within the audiences. Inspirational narratives based on personal activity, such as explorations of the unknown, or on suggestions that scientific knowledge is not fixed and complete but is constantly evolving in a world awaiting discovery, are to be encouraged. Such mechanisms may help to create a true sense of opportunity in science, galvanise a sense of excitement and wonder and ultimately help to create enduring moments of experience that ‘sing’ in the memory of individuals and provide an impetus for deeper engagement.

3. It is apparent that science heroes make their impacts felt by successfully negotiating the prevailing communication norms and counter-norms of science in both the professional and private domains; those at the peak of their influence must speak both as plainly and as technically, with as sufficient passion and detachment and as generally and as specifically required, to effectively reach and influence their audiences. Therefore, communication training for all scientists must be improved in order to better equip them with the skills and knowledge needed to be the best communicators they can be, to understand the substantial risks and benefits of communication, to appreciate the nuanced communication environments in which their work takes place, to be cognizant of personal communication narratives and motivations, and to develop both personal resilience and flexibility in their approaches to communication in order to meet the informational needs of different audiences.

4. In taking a broad approach to the question of heroes within science, this study did not explore disciplinary differences in any great detail. Nevertheless it was clear that disciplinary differences do exist and that to some extent these may inform the competing communication norms identified. Much further research is now required to tease out the more complex variations that undoubtedly exist within and between disciplines, to examine changes to these over time, and to test the findings as they have been reported here with further cohorts. Similarly, gender- and age-related issues that were not addressed in this study should also be further explored.
In conclusion, the present study made some inroads into identifying those communication traits and experiences most commonly shared by a cohort of science heroes, and it makes a start towards unravelling these in ways that may be useful to others. Revealed here in a fraction of their diversity, science heroes are evidently a rich source of knowledge from which much more useful information may be derived – and one, I hope, that future scholars will explore.
Sir Gustav Nossal
Emeritus Professor
The Department of Pathology
University of Melbourne, Victoria, 3010

Dear Sir Nossal

REQUEST FOR INTERVIEW: HEROES IN SCIENCE STUDY

I am a researcher from the Australian National University investigating the impacts that public heroes of science, technology and the environment have within society. As a great inspiration to others and a renowned biomedical scientist active in society today, you have been suggested as a potential interview candidate.

I would be delighted if you were able to join this study. The findings will have global relevance to science and technology communication practice and engagement, at a time when young people’s interest in science and technology education appears to be waning. Your participation could make a critical contribution towards understanding and addressing this problem.

Those participating at interview internationally span all areas of society, and to date include Nobel Laureates such as Harry Kroto and Rudy Marcus, science broadcasters David Attenborough and Robert Winston, environmental champions David Suzuki and Helen Caldicott, business leaders including George Poste and Kristine Pearson, many leading scientists and researchers such as Robert May, Alec Jeffries, Jocelyn Bell-Burnell and Wallace Broecker, and other renowned individuals from diverse fields. I am about to commence interviews here in Australia and would be delighted if you would consider participating.

About the interviews
If you would like to take part, the time commitment anticipated is from 40 minutes to 1.5 hours for a recorded interview. I am able to travel for interviews at a location and time that suits you. Interviews by telephone or email can also be arranged, if that is more convenient for you.

To respond to this invitation, please contact me in one of the following ways:
Email: bobby.cerini@anu.edu.au
Phone: 0415 032 701 (mobile) or 02 6125 7634 (land line)
Fax: 02 8088 6161

About the research
The study will also include further research into the role of scientists and the media in shaping public perceptions of science, technology and the environment. I would be glad to hear your suggestions for other interview candidates, and to share the results of the research with you on completion of the project. More information about the project is attached for your consideration.

I do hope to hear from you soon,

Ms Bobby Cerini
Centre for the Public Awareness of Science
February 17, 2009
Appendix 2 Consent form

Interview Release Form

Title of project: Heroes of science – image, impacts and inspiration
Name of researcher: Elizabeth (Bobby) Cerini

I (name of interviewee)

of (address) give permission to the researcher to audio and/or video record an interview with me which will be/was held on (date of interview): at (place of interview):

1. I agree that the following conditions will apply to the use of the recordings and transcript and any other material arising from the above-mentioned interview:
   (a) The interview will be transcribed.
   (b) The transcripts and recordings can be edited.
   (c) Transcripts, recordings and other material may be indexed.

2. I will be given the opportunity to review and correct where necessary any parts of the transcript selected for publication, prior to its finalisation. A copy of the recorded interview will be provided to me to facilitate this process.

3. On completion of work on the interview, I will be given a final copy of the interview and a final copy of the transcript, if I so request.

4. I assign all rights in the recording/s, transcript and other matter deriving from the interview to the researcher.

5. The researcher may allow others access to the materials described in clause number 4 for bona fide research and education purposes.

6. In any adaptation, broadcast, publication, public performance or any other forms of reproduction of whole or parts of the recording/s or transcript, my name may be acknowledged as the interviewee.

7. I allow the researcher to use my interview, name, likeness and biographical material in connection with the publicity for the research project and for other purposes related to the project, in any medium including the Web and portable media devices.

8. I release the researcher from any claim by me or anyone on my behalf arising out of the project and/or my appearance in publications arising from the project, and agree to indemnify the researcher in regard to such claim.

9. I further understand that the researcher is under no obligation to include me in the published works arising from the project or obliged to complete or exploit the project in any manner.

10. I understand that, prior to 1st October 2009, I can withdraw my personal information from use and/or request my data be destroyed, by contacting the researcher on bobby.cerini@anu.edu.au

To signify your acceptance, please sign, date and return this Release Form to the researcher.

Name of Interviewee: ___________________________ Name of Witness: ___________________________
Signed: ___________________________ Signed: ___________________________
Date: ___________________________ Date: ___________________________
Appendix 3: General information sheet

Project overview: Heroes of science, technology and the environment

About the project
This study investigates the social impacts and influence of those who represent science, technology and the environment in the public domain. This includes individuals nominated as heroes in these fields by non-specialist audiences and the media, and those who have inspired others into related careers.

The research involves interviews conducted across the UK, North America and Australia. Interviews are with individuals who have been publicly named as influential and/or inspiring in regards to science and technology. An international survey will simultaneously be open to the public.

The Human Research Ethics Committee at the Australian National University has approved this research.

About the Researcher
Ms Bobby Cerini is an associate lecturer and PhD candidate at the Centre for Public Awareness of Science (CPAS), at the Australian National University in Canberra. She has qualifications in zoology and science communication, and extensive experience working as a science communication specialist within the UK, Europe and Australasia. She specialises in the research and development of science programs and activities for young people, educators, business and government. Further information about the researcher is available online, at the websites listed below.

This project is supervised at the Australian National University, by the CPAS Director, Associate Professor Sue Stocklmayer. Contact details for both the researcher and supervisor are provided below.

Research within the UK and North America
The researcher will travel to conduct interviews in person in the following locations:

UK and Europe 7 July – 11 October 2008
USA and Canada 14 October – 4 December 2008.

Participating in the research.
Interviews will be audio and/or video recorded and later transcribed. Participants are able to participate in a live or telephone interview or provide written answers to interview questions. Any participant may withdraw prior to 28th February 2009, by advising the researcher in writing. Information withdrawn by this date will be excluded from any further analysis or publication.

Presentations about the research
In 2008 the researcher will present papers at the Science and the Public conference in Manchester, England and at the Public Communication of Science and Technology (PCST) conference in Malmo, Sweden. Media promotions relating to the research and the public survey will be conducted throughout 2008 and 2009.

For further information please contact:
Researcher: Ms Bobby Cerini
Email: Bobby.cerini@anu.edu.au
URL: http://cpas.anu.edu.au/researchprojects/
URL: http://www.linkedin.com/pub/4/757/b4
Telephone: USA/North American callers - (202) 657 4036
Australian callers - (02) 6100 7743
UK callers - 020 3239 2018
Mobile: +1 314 359 3585 (USA)
Fax: +61 2 8088 6161

Supervisor: Dr Susan Stocklmayer
Email: Sue.stocklmayer@anu.edu.au
Telephone: +61 2 6125 8157
Fax: +61 2 6125 8991
Appendix 4: Interview protocol

Interview questions – Heroes in Science study.

The following provides an overview of the interview questions asked in the course of this study. Each question is designed as a starting point for further discussion and reflection. This list highlights the major themes of the study and questions are grouped accordingly. The precise question order is determined at time of interview, based on the flow of conversation and ideas raised by the interview candidate.

Questions are often expanded at interview, for example by asking: ‘You mentioned.... Please tell me more about that.’

The questions asked will vary between interviews, according to the time available and context of the discussion. Not all questions will be asked of all interview candidates.

Identity

How would you describe your personal approach to communicating (your discipline).

What’s made you successful in (your discipline)?

Motivation

Why communicate (your discipline)?

What motivates you to keep going (in your field)?

What particular impacts do you want to achieve?

Inspiration/ Influences

What got you interested in doing science (or related discipline)?

Were there any particular people who inspired you?

What other inspirational experiences did you have (for example literature, film, fictional characters, experiences outside school)?

Relationships

How has the scientific community reacted to your presence in the public eye?

Have you noticed any change over time in how communication activities are viewed?

How would you describe your experiences of appearing in the media?

How do you think the media portrays the research in your field?
How would you describe your relationship with your public audience?
What kind of personal contact do you have from members of your audiences?
What do they contact you about and what do you think motivates them to contact you?

Values
What’s most important to you, in doing your work?
What advice do you have for people following in your footsteps?

Character
What personal qualities have made you a successful scientist?
What characteristics have made you a successful communicator?
Where did you acquire these qualities and characteristics?

Benefits/Costs
What have been the main benefits to you of talking about your work?
Have there been any negative repercussions, or negative consequences?
How have you handled the pressures of being in the media spotlight?

Training
What do you do to prepare yourself before speaking in front of a public audience?
What training or coaching have you had in dealing with the media or talking to the public?
## Appendix 5: Interviewee list

<table>
<thead>
<tr>
<th>NAME</th>
<th>ACTIVITY FIELD</th>
<th>REFERENCE SOURCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Johnny Ball,</td>
<td>maths, science presenter</td>
<td>PERS. COMM.; NESTA; C4; REFERRED BY INTERVIEWEE</td>
</tr>
<tr>
<td>Elizabeth Mills</td>
<td>biology, business, OBE</td>
<td>PERS. COMM.</td>
</tr>
<tr>
<td>Ron Oxburgh</td>
<td>environment, business, policy</td>
<td>REFERRED BY INTERVIEWEE</td>
</tr>
<tr>
<td>Robert May</td>
<td>earth science, chief scientist</td>
<td>NESTA; REFERRED BY INTERVIEWEE</td>
</tr>
<tr>
<td>Raymond Tallis</td>
<td>medicine, philosopher</td>
<td>REFERRED BY INTERVIEWEE</td>
</tr>
<tr>
<td>Trevor Baylis</td>
<td>technology, environment, inventor, athlete</td>
<td>WEB; NESTA</td>
</tr>
<tr>
<td>John Sulston</td>
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Appendix 6: Example transcript

Interviewer: plain text

*Interviewee: italics*

*Third party; assistant to interviewee: bold*

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I’m Barry Marshall, clinical professor of microbiology at the University of Western Australia. Nobel prize in medicine 2005.

Thanks for making the time to see me.

*Thank you.*

I wanted to start by asking you about your personal approach to communicating research in your field. You’ve obviously had a lot of experience doing so. How do you personally approach it?

*Well, I was a bit paranoid about it initially, cos you know the English way of dealing with publicity and medicine is not to have any. And so that time and time again you hear these sad stories of discoveries and things being done in England and Australia that never actually get commercialised or see daylight. And as a result of that, people don’t know about it, or don’t benefit from it. So I learned that lesson early on. And I decided that I needed to just be - have some common sense about it. Tread carefully initially, but I never really had any commercial gain out of publicity; I never had a private practice. So I could always talk about medical research pretty easily. And, in Western Australia once I started trying to recruit patients for a clinical trial, I realised the way to do it was through the media. Connect up the right way with the media, then people will be interested in helping*
you, and having new discoveries, testing out new things. And pretty soon after that I went and I set myself up and used to organise my own publicity. And then after that, I moved to the United States in 1986, and was very quickly upgraded to US-style media (laughs). And understood then how it all worked. At that point I realised that no matter how many thousands of patients I saw, it was not as good as being on ABC News, because I would be talking to thousands of doctors, who would see hundreds of patients.

Mm.

Or presenting a paper and getting in a bit of a to-and-fro at a important, national meeting in the United States was far more important than just seeing lots of patients and answering phone calls and doing the things I could do in my own practice or in my own hospital. So - so with the discovery with Dr Warren and I where - you know - feeling our way with the idea that bacteria cause ulcers - once we had convinced ourselves and tested it out to a certain extent, then all we had to do was let the word out. Because there were millions of people out there looking for a cure for their ulcer. And of course all these poor people were labelled as being psycho, neurotic wrecks with ulcer personalities and everything. But of course most of them were just normal people, so you can imagine how frustrating it is to carry a label around like that. And just - just because you've got something wrong with you. So, well, 'I feel like a normal person but my stomach hurts all the time and I feel sick', you know. There must be some answer to this. So there was always a good audience amongst the patients, but we had to sort of get through this barrier of doctors who didn't want to put the word out, and would deny it.

Mm.

So I then realised in medical research, it’s really a communication job. So you’ll do the research. At that point you’ve got to get the message out. Otherwise it’s wasted. Particularly - potentially you can imagine if you’ve discovered a cause or a cure for a fatal disease, every day that you do not get the word out, somebody dies. And peptic ulcer’s like that. So if you say that a million people a year were dying from
bleeding ulcers - I'm just guessing at a number, maybe it's not that much - but, so, you divide that number by 365, and every day where you just keep quiet and do nothing, there's a few people bite the dust, just because they didn't know about the new discovery. So there's sort of a moral imperative to go ahead and advertise important new discoveries. It would be immoral just to do nothing about it. And so, I became media savvy. And I'd be - because of my hobby, which is electronics, computing and all that stuff - I had my own Internet site when most people hadn't heard of the Internet. So I think I got my first Internet site in 1984. No, 1994.

That was early, yes.

So there was, there was, I had, I remember, if only I'd kept it, I had my first email was, barry@ibm.com (laughs). One of those really good short emails that I didn't pay the rent on. But in those days, you could get your name on important domains. So, I went around and rented my own domains. So I own several domains called helicobacter.com, hpylori.com, breathtest.com, anything that I thought would be relevant, I went and signed up for it. And so then when I - at that point I was doing a lot of media interviews about H. pylori, cos it started to catch on about 1994...

Mm.

Maybe it's because I was on the Internet. It really accelerated then, and maybe I didn't realise it was the Internet. But whenever I did an interview or a news article, people wanted to have a few illustrations and some photographs and resources, an article, stuff like that - just normal things. And it was always - oh right, I'm gonna send this photo, I wonder if I'll ever get the original back, you know, I've got to make a copy - so I was always forever sending off the same stuff. But once I had the Internet I realised that no more - and I had all this information scanned in and put in all different places. And so whenever people called me up, I would give them the website location for it and they'd say, 'http - what is that?'

Yes, I can imagine.
So very quickly, whenever there was a media going on, they would be able to get - obtain good media stuff for their journal or whatever it was from me. Up to the stage that by, ‘96, people were saying ‘gee, Barry, who does your publicity?’ Ha ha! And it was just me. Well, I had a few smart people in my office to help me do it. But we didn’t really have a publicity campaign running. We just made it available when people needed it. And so, and so one thing led to another, and probably my biggest circulation article was something I did in the Reader’s Digest about 1988 or 89. It was pretty corny I suppose. It was called ‘The Doctor Who Wouldn’t Say No’ or something like that. But apparently they reckon that’s been read by 360 million people. Which is in 60 languages from Reader’s Digest.

So a tiny readership!

Oh yes. So these days people tend to know about H. pylori. Although if you walk out in the street in Australia, half the people would still tell you that ulcers were caused by stress.

Mind you, most people seem to have heard of the stomach ulcer guys.

Okay. Yes (dubious), well, who were you talking to, though?

People often ask me...

*I had a limo driver who knew*

I’ve had taxi drivers who’ve heard about it.

*Oh, taxi drivers! But they’ve all got ulcers.*

And they know everything!

*They all have ulcers. They’re all Lebanese or immigrants with H. pylori, so that’s a hot spot for ulcers.*
I didn’t realise that.

I - I get a lot from taxi drivers and had a taxi driver in Edinburgh who gave me a bottle of single malt whisky because I’d cured him. I was just there on - at a conference, and he somehow was asking me questions and found out that I was the guy who discovered that ulcers were caused by bacteria. And he’d had the treatment.

Well I have to say I recently had to have a breath test and I would have - if it had been an ulcer I would’ve bought you a bottle of whisky as well.

Okay.

You’re so miserable when you’ve got those kind of symptoms —

Yes.

Terrible.

So you didn’t have it?

I had my gall bladder removed instead.

Oh!

Yes.

Much better to take antibiotics if you can.

That’s what I think. I just want to —

Oh you had a laparoscopic gall bladder out, did you?

Yes.
Oh wow. That’s pretty good.

Yes, well. It wasn’t my finest hour.

I can tell you the - the - the time I presented this first in the United States was this just big conference and they had about three thousand people plus side walls with projectors going there. And, the other technology that was announced at that conference in the plenary session was lithotripsy for gallstones. You know - smashing gallstones from outside the body? And that just went by the wayside because it was superseded by laparoscopic cholecystectomy. So that at that plenary session, mine was the weird third one that they had on that day. I can’t remember what the second one was. And everyone was so excited about lithotripsy because it was so expensive, and big machines, and high tech, and this one was just antibiotics, no interest. But of course mine proved to be the important one as time went by.

Absolutely.

Yes.

It’s amazing hearing you talk about that process of going to the States, and that you mentioned that you quickly gotten embedded into the US style of media. Can you tell me a bit about that?

Well my connection with the US was that I’d discovered that one of their important over-the-counter drugs called Pepto-Bismol cured, or killed Helicobacter, at least in the petri dish. So the - the vision for the company making Pepto-Bismol, Proctor and Gamble, was, lo and behold they had this over-the-counter medicine that was going to be the new ulcer treatment. So they were just in heaven as far as - it’s the best thing you could ever discover. So they funded my research for a few years. I think I was on about six years of funding with three or four salaries on it at the University of Virginia till 91 or 92. And then I went on faculty and did other things. Um. So if it’s an over-the-counter medicine, of course you can advertise it on TV. So these are marketing people who were funding me. Not scientific people. As much as
- there were both. But essentially it was out of the marketing budget. Cos they already had the product on the market. So I used to do a few things. And then I'd appear on the morning show in different cities.

Mm.

From time to time when I was at a conference. And I became a little bit cynical. And whenever I see any kind of health publicity now, I don’t take it at face value. I say ‘what’s behind that?’ And I’ll give you an example. If you show me a story about superbugs, how these antibiotic resistant superbugs are creating havoc in the hospital and somebody could die, etcetera, I immediately think somebody has got a new antibiotic for superbugs that’s gonna come out in the next twelve months and they want us to be worried about superbugs so they can sell their antibiotic for a thousand dollars a day. That’d be my best guess. Where does superbug publicity come from? Where does superbug publicity or research get funded from? And I’d say the makers of the next generation antibiotic against superbugs. And I’m probably right. I still think I’m right.

I was interested by you talking about the doctors who had prevented the story getting out, as it were, to patients.

Yes.

What was behind that, do you think? In the sense, what motivates a doctor who hears a bit about some research?

Well if you’ve got a new technology it actually requires a bit of effort on the part of the physician. He has to learn about it. So there’s downtime for him. And so he has to understand the disease and know the risks and benefits of the treatment, and what the doses are with the different antibiotics. And if the government just, if the government has this pack already made up which says - and you just write for instance for example, ‘H. pylori treatment Nexium HP7, take as directed’ - easy. But if it’s a new thing, when that was new, and it, you didn’t have it all in a triple pack for treatment for H. pylori, I’d have to write you know, what’s the dose of
amoxicillin, what’s the dose of neprozole, what’s the dose of clarithromycin [??], oh my goodness, you know. So you’d have all these prescriptions, and take this, and half the time the pharmacists would call you up and say, oh, if you give it this way it costs twice as much, and —

Mm.

— it’s three prescriptions. So the alternative is the patient’s just gonna take an acid blocker if he’s got an ulcer. And that’s been good enough for the past ten years. Why should I change unless I’m forced to? And also, you, the doctor’s got sweet spot in his practice where he’s most efficient. It might be fifteen minute visits. If you go to the next longest visit you do twice as much time and you only get half as much reimbursement or something, so the government tweaks the system to have the best balance of number of patients and amount of funding. So it’s a government funding issue as much as a GP’s, you know, money-grabbing personality.

Mm.

So he’s there and he says well, if I now tell this - want to treat this patient for H. pylori I have to do a blood test. I have to explain to the patient for twenty minutes what it’s all about. And I have to get the patient back and then yes and no, pros and cons, et cetera. It becomes a big effort up the front end to start telling people about Helicobacter pylori. So while it was the slightest bit experimental, people were not really going to do it. It would never become mainstream. Although if you wanted to have a special practice where you specialised in really tough patients, or if you’re in a public hospital, where, you know, it made no difference whether you saw one patient or ten, you didn’t have those constraints. So you could sit down and talk to patients and tell them all about it. And then, they would say, oh, if you want this new treatment, you have to go to the hospital and see the registrar or somebody doing research. So I think that’s how it works. So that’s how it worked in Australia. And then all of a sudden the treatment came on the market in a in a pack, promoted by a drug company. So that the drug reps then went around to all the GPs and explained it to them so they were all experts on it. And there was
information in the media. And there were sample packs. And there was a PBS prescription there’s just one line, whatever it might be. Then everybody can get it. So as soon as that happened, within three or four years all the ulcer patients in Australia were treated. So it’s just a few stragglers now. You can’t find ulcers. And it didn’t happen in Australia till it happened in America.

Mm.

Cos that is where the information flows from. And that is where the drug companies get most bang for their buck, when they put out a new treatment. So although it was kind of available in dribs and drabs in Australia, it was still hard work to do it. . In the United States, the companies that were going to get it approved did a really big study, and it took them a year or two. They got it through the FDA. As soon as it was approved by the FDA, this marketing campaign, a hundred million dollars of marketing just went out. And overnight, it was almost malpractice not to treat it with antibiotics. So in January, you didn’t want to do it, you didn’t have to do it. In July, all of a sudden, oh my god, you know, I have to treat it, I could be sued or something. This is the standard of care.

Mm.

So, once that happened in the United States, then there were - it was on the news, there was all kinds of media stuff going on for about six months, and then it was a done deal. And it wasn’t until the following year or the year after that it really was funded properly in Australia. And it got on the PBS.

Yes.

So I - I’ve got a lot of respect for marketing and communication. And but somebody has to pay for it, and in the United States the drug companies pay for it. So that’s part of their drug budget if you like. Maybe 50 million dollar launch in Australia obviously you can’t spend that kind of money. But there is there often is a bit of a launch out to the GPs et cetera when a new product comes along.
Yes. It’s so interesting.

Yes.

Because I think it’s one of those aspects of how technology gets adopted in society that’s a bit invisible. You know, to think about the marketing and the machine...

Yes, so the drug companies are always under the hammer, regarding their free samples and their junkets. But if you want to talk to a hundred GPs, you’ve got to take those people out of their productive job, the productive part of their job, and grab them for a couple of hours, and convince them you’ve got a new treatment of some advance. Otherwise it’s - they - you can’t rely on them doing it. It’s like taking someone away from his - if he was a carpenter - and say, right, next week I’m going to tell you about new kinds of pine or some carpentry thing, and all these guys earning you know two hundred dollars an hour at some job, and all of a sudden they earn nothing for two hours and learn about something. It’s hard to convince people that that’s - they’re gonna get that information, that value back.

Yes, sure.

So in the States it’s obvious that private industry, pharmaceutical companies do it. In Australia, it’s harder to do that because it’s not as lucrative for them.

Mm.

So I don’t think you can necessarily count on the government to do it as well.

I wondered if you could tell me a bit about your relationship with the media, and in particular how or whether it changed as a result of winning the Nobel Prize.

Okay. So I was always media savvy. And it was always easy to find people in the media who had ulcers. And they would find me as much as I would find them. So I used to wonder why journalists got so many ulcers. But once I decided it was an
infectious disease — I’d say that we don’t want to go into that any further! But, er, they’d caught it off their partners, or they travelled to Nicaragua or something and picked it up in the water supply. A lot of reasons why journalists would have more ulcers. So once it was an infectious disease, it wasn’t related to all that crazy stress, deadlines. It was just that they picked up a lot more germs than other people, because they were gregarious meeting people. So that’s an aside. So the question was how did I use the media in the US? Is that what you were saying?

No, it was, how would you characterise your relationship with the media, and did that change when you became a Nobel Laureate?

My relationship with the media was always very positive and I was always accessible to them via - to the media. I always made myself accessible because I was receiving a lot of support from patients and doctors long before it was official. And that is because I knew there was a pent up demand, which was tapped by the media. So I owed a lot of favours to the media, I can say that. Numerous anecdotes related to things that happened that were useful for me because of the media. And so about twenty important events in my life were so - triggered by a news story or a journalist called me and told me something. So that would happen. Now once the - once I got the Nobel Prize it became a bit inundating if you - that’s a word.

It can be now. I think it would be a word for most Nobel Laureates, wouldn’t you?

(Laughs.) Yes. So you cannot - it’s impossible to manage it once you win the Nobel Prize and it - as soon as the announcement goes, you could then spend the next six months on the phone if you wanted to.

Mm-hm.

So Dr Warren and I spent that first night on cell phones and our batteries went flat of course. So there we were borrowing other people’s cell phones, and we had the media office at the university channelling calls through to another cell phone which no one had the number of. So that straight away we controlled the - called the
media office. Probably because I was media savvy I knew that this was getting out of control. So at that point we had the hospital and the university media office, organising the calls. So they would organise us, organise it on one phone, and then we’d get the call on another phone so that it was manageable. But we noticed that drive time interviews were the trap. Because you realise that drive time travels around the world with the time zone. So there’s always drive time somewhere in the world. So if you start saying okay I’ll do drive time, that’s pretty important. Of course you do Sydney drive time, Melbourne, Adelaide, Perth, Hong Kong, China, Thailand, you know. It - and you end up you’re doing South America drive time six or eight hours later. Then you’re doing morning drive time somewhere else, in Sweden [???], so. And the - so that was one thing I learnt - you can do you - there’s always another interview you can do. So you’ve just gotta draw the line somewhere. The second, point is that there are different types of journalist. Some journalists will do their homework. And others are just talking heads. And so that if you are just one of these talking journalists, then you might be just told to do an interview with Barry Marshall and do this, ask these questions. And you know nothing about it. It’s a bit hard to interact with people like that. And the other point is that the editor’s probably already written the story, and out of ten questions you get asked, only one of them is important, and they just want you to say ‘yes’ on this question. The rest of it is thrown in the bin and you become part of a headline on a tabloid newspaper. So that’s happened to me. And so I occasionally get caught. But, as a Nobel Laureate I think there’s a responsibility to be credible. And so that after the first day or so, Dr Warren and I had a meeting with Chris Laurie and started the office of Nobel Laureates. So that if someone wants to do an interview a - with us, the question would be ‘is it relevant to what we do?’ There’s no point asking me an engineering question. Actually I’d probably know the answer - I’m quite interested in engineering. (Laughs.)

But if it was something a bit out of our field, it’d be better that we didn’t actually do the interview. Otherwise it’s a waste of our time and/or a waste of everyone else’s. Um. The second thing is that we can’t do every single interview, and we would try to do interviews, get information out, where people with ulcers for example or people with stomach trouble can get, obtain some useful information out of it, and
perhaps, point them, get pointed in the correct direction on websites, other resources. And then, the other thing we could talk about just general research and health questions. So we have, cos we’re the Nobel Laureates, if we say something 'gee there needs to be more funding on this, it’s obvious that the government should put money in', the usual kind of thing that academics say, maybe because we’re the Nobel Laureates, if someone says ‘oh, Barry Marshall or Robin Warren said this, it’s more likely to be true cos they don’t just say anything'. So it’s important that we don’t just say anything. So, so if it’s something we’re not sure about, but we think it’s important, we will have our office, and spend a bit of time ourselves on the internet, make, perhaps make a few background phone calls ourselves, and make sure that we’re not just giving off the cuff remarks, but if we make a remark about something that we’re not a full bottle on, at least we want to be in the ballpark, and have some knowledge as to who does know the answers, where they come from.

Mm. You say that as though you’ve had experience of not necessarily being caught out, but maybe the phenomenon that seems to affect other Nobel Laureates. And Peter [???] described this at a conference in Sweden last year, he said the temptation to speak outside your area of expertise is immense because journalists assume that you know - they’re using you as a public expert and so they ask you about all sorts of stuff. Have you had experience where you’ve felt that you went too far?

Um . . . I’m sure, I’m sure there is. But, generally, perhaps because I’m a bit careful, a bit savvy —

Mm.

I think it’s happened to me over the years. Long before the Nobel Prize.

Mm.

So I . . . Robert Macnamara, he said it, people have said it to me - don’t answer the question they ask you. Answer the question you wished they asked you. Ha ha! So that’s that’s the way to do it. And the other the other thing is don’t be too, you
know. Everyone’s gonna make mistakes. But you don’t want to waste your whole life wringing your hands, sack cloth and ashes, oh no, I screwed up. Because media is very, very transient. I think medical research - you know, each thing you do is like a building block for your career. So you’re going to end up there and it’s based on all this other stuff you do. . I suppose there’s a bit of that in the media, but in fact, even if you have a very high profile story about some research on the news, ten per cent of the population saw it, ninety per cent didn’t.

Mm.

So. Of course the ones that saw you screw up will be (laughs) will take delight in asking you about it (laughs). So that - that’ll happen. But you don’t want to just, you don’t want to worry about it too much.

Mm.

Someone else - in Hollywood they’d say there’s no such thing as bad publicity. And that is almost - that’s kind of true. In that, if you have some bad publicity and no one’s ever heard of you before, obviously it’s to your benefit one way or another. Because you might be the focus point of some controversy which develops. The best example is today’s papers. Poor public servant sent a fake email and they’re interviewing him from his hospital bed in a psychiatric hospital. So he was the fellow Gretch.

Godwin Gretch, yes.

They’re interviewing him, he’s in bed, in hospital making his statement. So he’s probably gone too far, and he’s, he’s now worrying about it a bit too much.

It’s a quite a massive machine really, the media. As you pointed out...

It’s actually quite hard to penetrate. if you have got a message, and you don’t know how to do it, it’s very hard to penetrate the media or a lot of these big institutions, drug companies, for example. And I had no way of doing it when I was starting off
in the 80s. I could write to politicians and the minister for health and drug companies, and nothing I did went anywhere. And then I suppose I had some media contacts, so that I bypassed the conventional pathways and got straight to the patients. So that suited me at the time. But it’s - it must be the same, it’s very valuable to - if you’ve got something to sell, or something that you want done, media time’s very very valuable. It’s worth anything. So it has to be filtered I suppose.

What do you do to prepare yourself for a media interview?

Me? Um. I try to be fresh. So I’d much rather have an early night than sit up worrying about it too much and trying to be a full bottle on it. I think media interviews are - I think most journalists want what - to show you in your best light, so you have to trust them that they’ll cut out all the bloopers and put the good bits in. So usually they’re pretty reliable on that. , The second thing I’d do is - oh, I’d usually do a Google search, and perhaps just look at a few online researchers and just, so that, because if there’s a question from the media often it’s because there’s something that triggered it. I’ll say, well why am I getting this question, what’s been going on. And nine times out of ten you can figure out what exactly is happening. And with me, because I’m a Nobel Laureate now, I can - they’d pick up the phone and I’d call whoever it is that is creating the media and say, what’s going on here, you know. So I can usually find out exactly what’s happening. And so I often give a pretty balanced view. And so quite often there’s a beat up story about for instance beat up the drug companies or beat up somebody or somebody, you know, numerous different angles to it [something??]. The stem cell one was a good one. There was always a stem cell story. And I kind of got involved with that. But really I’m not a stem cell expert. So I’d have to just know - more know a person, I think. That used to go on. So I do that. The second - the next thing would be, I’d take a powernap if it’s in the afternoon and have a cup of coffee before I did it. I would assume that no matter how bad I looked, Australian TV crews are not gonna turn up with any makeup or anything. So I’ve seen myself look like I’ve got a five o’clock three day shadow, and I’m on the cover of a magazine, so (laughs), I think a little bit about that. I might just brush and give myself a buzz if I’m carrying my portable
shaver. And, if it’s a hot day, I might grab my secretary’s powder and take the shine off my head. Course there’s less hair there nowadays, so —

(Laughs)

— I can’t trust it. And I’m prepared to, and I usually talk to the hospital media person or the university media person so that I can arrange parking spots for people, it’s not too rushed. I will go, give a heads up to the laboratory people in my lab, so that they can have a place where you can do an interview if they want to do a lab interview. And usually a very noisy machine’s around in labs, so that they might have to turn the machine off for twenty minutes, and that’s a bit of a concern because these very valuable samples are in these machines, so there’s many issues like that. And that’s about it. I try to give short answers.

What’s the value of a short answer?

If you can give a one sentence answer, then it - the whole answer will be on the TV as you said it. Whereas if you, waffle on and on . . .

Mm.

And I’ve seen too many scientists want to qualify it twenty different ways. And at the end of twenty seconds of talking, you still haven’t got the answer you want. At this point the fellow reading the news pretty much cuts in and says well, thanks very much Dr Marshall, off we go. Everyone’s saying ‘what is he saying?’ The other, the other trick that is important in technique is to repeat the question before the answer. So if you say, ‘what’s the latest stuff on Helicobacter’, I wouldn’t just say, ‘well we’re very interested in the DNA’. You gotta say, ‘The latest thing on Helicobacter is . . .’ That’s wow, this is great.

I can tell you that there’s a problem I think in Australian media, particularly on the radio, talkback shows. The ABC DJs - they’re DJs I s’pose - are not commercial- if you come through the ABC, you don’t have this commercial feel. You’re not announcing a product all the time. And quite often, you come in about one minute
into an interview which goes for another five minutes, and you’re saying, ‘what is Norman Swan talking about? what is it? what are we talking about here? this sounds great!’ You get to the end of it, you say, ‘I don’t know!’ (Laughs)

(Laughs)

You go home and you get a podcast or something, and you try to figure out what was, what were they talking about in the first minute. And so that, you need the, you know, every sixty seconds, ‘well I’m talking with Norman Swan about the latest treatment for arthritis. A new drug’s been released.’ And you know, you need to say that every minute. Otherwise people just don’t know what it’s about.

So is that something you do when you do an ABC interview?

Yes. I try to ... so they say, ‘well, Barry, tell us the latest thing on Helicobacter’. I say, ‘well you remember we won the Nobel Prize for discovering the germ that causes ulcers and it’s called Helicobacter.’ And I’ll keep saying it every now and again. Otherwise people get in there and they say, ‘what kind of a virus was that?’ You know. Means nothing.

That’s a really good point. And that hasn’t come up - no one else has suggested that. And I wondered whether you could...

So annoying. Well now that I’ve told you about it, you’ll hear it time and time again as you go around. You get in the car, you switch it on, ‘what is this? what am I listening to here?’

And Norman Swan’s a really good example cos his stuff is so interesting, and you do hang onto it.

I’m probably - it’s probably unfair. He probably knows about this.

(Laughs.) Sure.
I think he does, you know, reintroduce it several times. But I can tell you that, quite often on the morning shows on ABC, or, evening shows, there’ll be someone, and they haven’t really thought about it. And they don’t realise there’s thousands and thousands of people continually switching on and switching off. And, you know, how long are you going to listen to something before you say, I give up, you know, let’s listen to music.

Yes.

It’s just right underneath your thumb now on the steering wheel, you just click click click click channel surfing!

And you’re quite right. Because if you don’t hear it within thirty seconds, you’re just gonna move to something you do get.

And who is this person?

Yes. And why should I keep listening to him?

Mm.

I wondered whether you could just talk a little bit about the differences between US media and the Australian media. Do you see that there are any? I mean, did you notice any?

Oh, I’d say obviously my, you know, ulcer research has always had a pretty high profile. So it’s relatively easy for us to get on the news if there’s a discovery. And everything’s resourced much better on the big networks in the United States. Though they really do have a newsroom with scientific people in it. People with PhDs, and journalism degrees et cetera. whereas I think it’s it gets a bit thin on the ground once you start getting out to the local networks. They might have one person. And a news reader. And then so in Western Australia it’s patchy whether you have a person who has really put some effort into a news story, or it’s just copied straight off the fax machine. And say, right, let’s get some local colour, go
down to Dr Marshall and ask him how many million people died from ulcers this year. Or some question like that. And you know that - well I’m okay with that. I know that it’s just going to be three seconds, and there’ll be some other story, and then pop a bit of local colour. So I understand that. I lot of people don’t. And they will think that they’re going to do a ten-minute interview on the news. And I know that it’s going to be ten seconds. And it could be totally - it could be left off or might happen next year. So just be aware of that. So is that what the question was? The difference between media?

Okay, so if I, if there is a news story about ulcers, Dr Tim or somebody from ABC News will book it a few weeks a week in advance, there’ll be a sound man, a camera man, and a man another person in like a research person with a script, and then there’ll be a celebrity doctor or somebody who’ll sit down, and he has researched - no, he’s spent a few hours reading it on the plane thinking about it. So it’s a proper news story that you’ll get if it’s on NBC or ABC news. And so you should be prepared for that. It’ll be good if your university had some advance warning, if people in the lab knew what was going to happen. You know, you were set up for it. If it was, say, Channel 7 or Channel 9, they don’t have those resources. And the person who interviews you has to do five other stories - a building burning down, something at the courts, you know, they’re running all over the city. So they can’t be expected to know all about H. pylori. And so then it, if you can do your research, you say well the interesting thing is this - why don’t you ask me this question and that question, and then it happens, it all happens in ten minutes and it’s done and it’s successful. So it often helps to try and figure out what the questions are that people will be interested in this month. And then you’re at a big advantage. And the journalist goes off, it’s effortless, and ends up with a tape that’s quite interesting.

I get the impression that journalists would love that.

Yes. It makes them look good.

Like they did all the work!
Yes!

It’s fascinating talking to you. I think that you and other Nobel Laureates I’ve spoken to have got this experience with the media which so few scientists really tend to get.

Mm. Probably, just from the amount of it, the other thing is that you don’t just get a Nobel Prize out of the blue. Although you don’t know - there’s plenty of good discoveries, so you never know that you’re going to get it, you’re gonna win it. But the Nobel committee likes to see that you’ve been mentioned in the media and you’ve won lots of other prizes. So that the CV of a Nobel Laureate consists of several other international prizes in different countries. So Dr Warren and I have got such a CV. We have won, if there was in quotes “a Nobel Prize” for each country, we won a couple of US Nobel Prizes. The main one is the Lasker Prize in New York City. We won the German Nobel Prize. We won a few prizes, a couple of prizes in the UK. There was one, a medal in the Royal Society that I won. And we won the Thai Nobel Prize, which is called the Mahidol Prize, pronounced Midol. And we won a couple of prizes in Australia. So the Nobel committee, by the time you win the Nobel Prize, you’ve done interviews for ten years —

Mm.

— about these other prizes. And the best example of the prizes is the Lasker Prize. Now I think there is actually money attached to it. It might be ten thousand dollars. The Lasker committee, they are very high profile scientists, so it’s a great committee and a great jury if you like for their prize. So no effort is spared. But the ceremony and the party in New York City must cost them a couple of million dollars I think. So they have a Lasker Prize office. Maybe three, a couple of publicity people, and medical writers in it, that work around the year, running this thing for the Lasker Prize. And then, no expense is spared to get publicity and a great party for everybody in New York City for the Lasker Prize. So it’s the most fabulous thing. And once you’ve done the Lasker well you say oh, I’m kind of confident that I could be okay at a Nobel Prize. Nothing could be bigger than this. But it is.
Yes.

Um. So by the time you do the Nobel Prize you do actually have Nobel Prize coaching. A lot of media coaching so that it goes smoothly. But usually you’re a bit experienced by then.

Yes, that makes sense. It’s not something that’s come up yet either —

So it’s a big responsibility with the Nobel Prize. It has to be an important discovery. And it’s important that everybody agrees that it’s a good one. Otherwise... cos a couple of times over the last hundred years, the Nobel committee has made a mistake. And awarded a Nobel Prize which turned out to be wrong! So you can imagine this big responsibility for them and they get a lot of, they receive comfort by seeing that you won prizes in other countries that were a big success as well. So it’s fair enough.

Yes, yes it is.

So I know that now, but it’s not something that ordinary people would be aware of.

Mm. I want to move to asking you questions about your early career, your early life actually.

Yes.

Why medicine?

Well I think I was sort of attracted to it anyway because my mother was a nurse. And of the books, you know, we were moving around, had a family of four kids, we didn’t have a lot of money, we didn’t weren’t the first family on the street to have a TV or a phone or anything, or a car. And but and so we didn’t have a lot of books in our house. Although I was a keen reader. But some the books that we did have would be the - my mother’s nursing books. So she probably had three or four textbooks. And they would have interesting pictures of babies and human bodies
and all of this kind of stuff that you imagine are pretty normal in textbooks. So that was interesting stuff to read about. We’d see the doctor coming to give us injections. We’d be breaking our arm and going getting x-rays down at Fremantle and things like that. So we had plenty of interaction with medical stuff. The other thing I had were my dad’s trade books. So he was a mechanical fitter. But he had a, I think he had a railway steam engine ticket, a diesel caterpillar ticket, and he worked on marine diesels on whaling boats, so there was all those kind of technical books as he’d done his trades. So I knew a bit about electricity and mechanics and I even knew, he then did refrigeration, so I knew even about weird things like entropy when I was about twelve years old. Entropy was some interesting concept in thermodynamics. And people kind of are vaguely aware of entropy nowadays. But it was something that hardly any kid in Australia would have ever heard of when I was a kid. So I was going to be in science or engineering. Also of course interested in dinosaurs and volcanoes and all that stuff. Explosions and gunpowder. Chemistry. So I always loved all that kind of thing. And I was a bit frightened of mathematics. This story’s in the Nobel website et cetera. But the first, in year eleven at school I had the flu for two weeks right when they were learning linear algebra or something. It was one of these difficult concepts. And I never really picked up, I was never confident on that area of mathematics. And I had the feeling that I wasn’t very good at mathematics after that. So I scraped through. I don’t know, I got 65% or something. And I liked, I was good at calculus and different other things. But I felt that I wasn’t good enough at mathematics to do it easily. So that steered me a bit away from engineering and electronics and I did medicine. I found that medicine was also requiring some mathematics once I got into statistics. Anyway so I still had a bit of trouble with mathematics there. But in retrospect, I think it was that illness, cos I don’t really have any fear about mathematics anymore. I know I could do it if I wanted to.

Mm.

Anyway so that got me into medicine. And that was biology and chemistry.

Mm.
And I found that I was also very good at medicine - well, I was okay at medicine, let’s say - because I had a lot of confidence with practical procedures and instrumentation, gadgets. So you could put me into any new ward with some new ECG machines and or monitors of some sort, and I’d be interested in reading the manual, figuring out how it works, playing with the dials, getting it all going. And if it was broken I could get it started up again. So I realised how important that stuff was. With a lot of people were not confident with machinery of any kind. And I was interested in it. I was interested in actually pulling the guts out of it and seeing what the circuit board looked like, what processor was on it. Cos I was building computers. So it was a fun time to be in there because I graduated in 75. So between 75 and 85 I was making, doing my H. pylori stuff and research. But also doing computers and electronics, building a computer and making my own word processor, and being right up on the cutting edge with all that technology, which actually helped me. Cos I could, I had an answering machine when nobody had an answering machine, and I had email when people didn’t even know what it was. I could communicate with people in South America in 1982. I was doing online literature searches before people realised how valuable they were, how much time they saved you. So being in medicine was a great way of also doing electronics and getting value out of it. And nowadays, there’s hardly any difference between the two areas. Information technology and medicine are the same, particularly genomics. So that it’s like it turns out that when I went to the genome centres a few years ago in the US, I found out that the software they developed to look for genes in great megabases, megastrips of DNA, was actually the same as the search and replace algorithm in Microsoft Word. So the guy who wrote search and replace on Microsoft Word, you know with a two hundred page document, go straight through - it’s exactly the same as looking for a gene in a big line of DNA. So it’s now the same.

I’m not sure that anyone else that I’ve spoken to would agree that doing medicine’s a great background for doing electronics or vice versa. But it makes perfect sense, the way you describe it.
(Laughs) Well I yes, so you’re talking, you’re talking about the media, so I realised early on that it’s a communication business.

Mm.

And...I’ve got a great story that, it well - you know I was saying that I got on the internet and I had my own website, people could email me, et cetera. We did an article about ulcer bacteria for the Parade magazine, which is the lift out for the Sunday Times in the United States. It turns out that they circulate this to 40 million homes in the US. And I didn’t - they franchise it out. So of course I ended up with this article that was read by 40 million lay people. So ten per cent of those people would have been taking treatment for ulcers. So that’s 4 million people. Four million ulcer patients read about me. But I had email and a website. We put our mailing address on it. A week later, the post office called me up to complain that the whole place was - we had one little post box of course and they had six rubbish bins full of this mail that was coming in.

And what were people writing to you about?

Well we said if you want more information, send a stamped addressed envelope to this. So people couldn’t be bothered buying a stamp, so they would just put two dollars in an envelope. So we probably made ten thousand dollars just by extra money that we had. Ha ha!

Ha ha!

So then, then we got the volunteer ladies at the hospital to come in every weekend and just stuff envelopes for us. And in the envelope we said if you want to find - if you really want to know all about it and take a treatment recommendation package to your doctor, send us ten bucks to cover shipping and handling... A month later, I had forty thousand dollars in the bank. So I started a research foundation and got tax exempt status because I said 'I don’t want to give this money to the university, I want to be able to spend it on my research. So I started a tax exempt foundation.
And I funded a research fellow for about a year and a half just on stuff that came in from that one article that I did.

That’s incredible...The power of the media.

Yes. That’s how it happens.

It’s shocking, in a way. That so much can happen out of one article. And as you said you had this experience of people wanting to communicate with you and they did . . .

Yes, a lot of people in science regard it, the media, as a hassle and an inconvenience. But if you treat it as one of the aspects of your job . . . Well, if it’s dealing with patients - it’s very easy for me, cos I could always see, well, somebody had their ulcer treated, and they would have had surgery tomorrow. So it’s very easy to justify it on, on the ulcer basis... So a lot of people would regard it as a hassle and wouldn’t do it properly, and it would become a hassle, and inconvenience. So people in my lab, you know, obviously, it is a bit of an interruption in the day’s work to have a camera crew turn up.

Mm.

And you learn. Also you learn that, ‘oh, can we come and do an interview, it’ll just be a couple of questions, and it’ll just take ten minutes or so’. It never happens. There’s always like twenty minutes set up time, or half an hour’s set up time, and then, you know, you can’t work in the lab for an hour probably while they set up the lighting. Otherwise you end up with an interview that’s terrible. So you - it’s a waste of time doing it if you don’t do it properly.

It was interesting hearing you talk about the books. My mum was a nurse, so while I remember her textbooks so clearly, I was fascinated by the pictures of all the diseases.

Mm. Mm.
That to me was quite fascinating. I wonder whether you had, when you were younger, particular heroes in science or technology. Or people you looked up to...

Well, I used to read when I was about ten or eleven or twelve I started reading novels. And so I used to like these biographical novels. So they must have had them at school. They probably had a series of them and I just went right through them. so Thomas Edison was pretty exciting because I could do things that he did. You know, I’d make a Morse code set. So that was an interesting story. And then a few years later I read one called ‘Brother Surgeons’. Actually I read about the Mayo brothers, who started the Mayo Clinic. And that was in a Reader’s Digest - Digest condensed book. So the condensed novels in Reader’s Digest. My life was pretty boring as a kid, and I used to read this stuff.

So you could get through the story in a night. So I read about the Mayo brothers and they were pretty exciting. They used to operate on their puppy, and then they grew up and started the Mayo Clinic about 1910, I think it was. An interesting thing is that the biggest disease in the United States was actually ulcers and stomach cancer in those days. And so the Mayo Clinic was actually built on the top of H. pylori. If it wasn’t for H. pylori, they never would have bothered starting it, because nearly all the surgery they did was actually stomach.

I mean it’s interesting that you ended up in H. pylori.

Yes.

Is there a direct connection?

Not really. The other one I read was Brother Surgeons, which was John Hunter, William and John Hunter. And William Hunter was a bit more studious and academic, and he had a museum and a surgery up in London, up in Edinburgh. And John Hunter was his rough younger brother, who probably had ADHD or something. Went off to the war, and used to do nice anatomy, and found out how to cut people’s legs off in five seconds, and . . . And often not do amputations because he knew the anatomy. He said you don’t actually have to cut this one off
because the artery’s still there. So he did a lot of important stuff. And he ended up - so the - he self experimented on himself, you know. His theory was that gonorrhoea and syphilis were really the one disease. So he infected himself with some gonorrhoea, and it just caused a pustule on his arm, I think that’s all it was, maybe... I dunno, maybe he, you know, did the real thing. , But the story is that he accidentally also infected himself for syphilis, with syphilis. Because he was wrong, it was really two diseases. And the syphilis was silent until he dropped dead and had a massive ruptured aneurism while giving a lecture when he was seventy - seventy years old. That’s the s - the folklore, I don’t know how that true, how true that was. He probably just died from a dissected aneurism or something. So Brother Surgeons is a great story about these two, young doctors, young medical students, who, you know, dug up bodies for the anatomists and were doing all this stuff in 18th century England. So a pretty exciting story. So I had those. And I really just wanted to be a GP. Cos I - in Perth, in the fifties and sixties, you could be a GP, or maybe you could be a radiologist or something. There was not really this concept of medical research . . . I never had it. I just thought, wow, I could cut and sew people up, you know, surgery, all that type of thing. And then it was, when I got into medicine, then I, then they, then I realised there was a very interesting intellectual problem-solving part of it.

Mm.

So it was like an Agatha Christie novel. If you could put the clues in the right place, you could connect it all back to one illness. So you might have five different things the patient’s telling you, and some weird signs. But if you know your stuff, you can say, well one disease actually explains this, this, this, this and this. And that’s, that was the joy of medicine for me. And that’s internal medicine. So everybody said ‘what is internal medicine?’ Well, you’re a doctor but you don’t do surgery. Not usually. ‘Ooh, that must be boring.’ Well of course it’s actually pretty interesting, cos that is the intellectual side of medicine.

So you’re talking of when you, once you get into your career, once you start to go down a certain path, other ideas about it open up to you. Were there particular
mentors or role models you had as you went through your career, who you think were instrumental in you ending up where you did?

Well, whatever type of medicine I did, so in, in your internship, you do something different every three months, so that you’ve had a broad experience for, so you do that for two years. Whatever I did, I’d come home and say this is fantastic, this is what I want to do, this is the best kind of medicine, so exciting and interesting. And so after two years of that, it became obvious to me it didn’t matter what I did, that I would enjoy it. And I then steered away from surgery and away from obstetrics and gynaecology because I felt it was too easy. Like the patient comes in with appendicitis, you cut his appendix out, the next day he’s better, and the third day or fourth day he goes home. OBGYN was kind of the same. Some woman, she’s going to have a baby. You get the baby out. It’s all over. Everybody’s happy. It’s great, wonderful outcome. So I could see, it seemed to be that that was, you know. There didn’t seem to be enough to it. I’d say well out, over the last two thousand years, people have figured out how to deliver babies, there’s not much else that you could write about. It’s a natural process, you know, so, it was, it seemed to be limited to me. So it wasn’t as challenging. So I went - headed off to internal medicine, and so, tough stuff like diabetes, vascular disease, hypertension, renal failure. They were, you could never ever learn it all. It was continually evolving and changing. And being able to take a, to develop rapport and interact with the patient, cos I - I realised early on that 90% of the work was talking to the patient, and getting the patient to want to tell you everything that you needed to know. And so then I would - and, I’ve always, said this in tutorials with the patients, with the med students. After you’ve taken the history off the patient, 90% of the time, you already know what you’re gonna find. And then, so when you put your stethoscope, the stethoscope on the patient’s chest, you, you are listening for that one little click or one little murmur that you’ll hear in about three seconds, because this is, this is the answer to the problem. You’re not putting it on saying I wonder what I’m going to find, ooh what’s that. You know, you should already know what you’re going to hear. And that tells you you’re doing the right job. So, that was where I wanted to be in medicine. And I wasn’t obsessional enough, so I was never perfect in any one specialty. And I actually used to like geriatrics, because the patients had six things
wrong with them. And so you could actually work on six diseases at once. So it was, I used to find geriatrics quite exciting!

That’s a funny thing about geriatrics. A specialist in geriatrics said he got into it for a similar reason, which was that the only time of life where the medical specialists are allowed to understand all these different diseases.

Mm.

And you need to understand the whole body...

And you actually feel that tension because you fix up one thing and it’s, something will break somewhere else.

Mm.

You wouldn’t want to… for instance, someone comes in with a high blood pressure, say it’s two hundred. Well they’ve probably been running on a hundred and seventy for the last ten years. So you don’t want to bring it down to a hundred and twenty, otherwise you’ve got a stroke on your hands. So you would say, well, okay I understand that. Let’s just bring it down gradually over the next three or four days cos this person’s used to it. And thyroid trouble, you don’t just give them a full dose of thyroid, you start them off at tenth the normal dose, because they’ve had it for ten years, that type of thing. Otherwise something else will go haywire.

Mm.

So it is very, very interesting medicine. So I was quite happy to go into geriatrics, and that’s when I came across the Helicobacter thing.

Oh, right.

Which was fun in a different way, so I, I found out that I really had to do it myself, nobody was going to take, take it over, and hand it to me on a plate, and say ‘you
can do your normal career and you’ve discovered the cause of ulcers as well’. I - you know, it was a battle at that point, and somebody had to fight it. Because it was life and death for various people, I was prepared to do it myself. I said there’s nothing that I can think of that’s more important than focusing on the H. pylori issue, and getting that out of the way.

There was something in the story you mentioned, I think it was the brothers, the surgeon brothers . . .

*Mm.*

About their self-experimentation.

Yes.

And that’s a big factor in the whole *H. pylori* story.

*Mm.*

And I spoke to Frank Fenner recently as well, who obviously as you know was involved in Myxo self experimentation.

*Right. So his experiment sounds particularly scary to me!* Imagine *having a brain virus or something!*

But, I mean, nevertheless you guys went out there and —

*Well it’s actually confidence in your own ability to assess new advances in science.*

*Mm.*

*So you see something and someone says, and you talk about it, or you try to write it up. And it’s only one case, or something that you did, and it seems to make sense. Well, of course the editors, most people would go and say well, you know, it’s anecdotal. It’s your opinion about it. And so you, you step back a bit and say well*
am I a complete idiot? Or did this really happen? And I say well, I saw this guy, he had ulcers. He seemed like a normal person. He told me he always had ulcers every wintertime. And I gave him antibiotics and got rid of this bug, and two years later he tells me he’s fine, and it’s the best thing he’s ever had. So, am I going to believe him or not? Once that’s happened to you two or three times and you’ve got this story —

Mm.

Well you say well, you know I’m not imagining it. There’s something going on here that’s related to the antibiotics. So you have to have that confidence. So with Frank Fenner, or with me, say take Frank, he does ten years of research into viruses. And he knows all this stuff about it. He knows that this cannot infect humans. He’s had, you know, all kinds of, he’s been playing with it in his lab, eating his lunch in the lab probably.

Mm.

Because in those days you never cared too much about that.

Mm.

Sucking blood samples up through pipettes, so that he would have been totally contaminated with these. So when they did the experiment and took the Myxo virus, they were probably immune to it. Cos if it did infect them, they probably caught it ten years ago. Anyway, so the whole experiment was rubbish.

Mm.

They could have, they could have got the wrong answer. (Laughs). And said it doesn’t affect humans, and then the whole, half the Australian population could have been decimated from it

Mm.
Because they were already immune, cos they’d worked with it, see.

Mm.

So that’s the down side of self-experiments

So, did you know that?

We tried we tried to keep that quiet. (Laughs)

Yes! That’s really interesting. You’re quite right.

Yes.

It’s a PR stunt!

However, at the time, it obviously, you know, was an important discovery that they made. And you didn’t want the whole population becoming paranoid. They couldn’t do anything about it anyway. So from what they knew, it was a safe experiment and they went ahead and did it. And they say it’s pointless telling people it’s safe if we haven’t got any proof and we’re not prepared to do it ourselves. Otherwise no one will believe us. So I can see a number of reasons that justified that. Now in my own experiment, I had by 1984, Robin and I had been working on this thing for three years. So we treated a lot of people. I treated people successfully with antibiotics. I knew which antibiotics worked and which didn’t. I was pretty confident that I would be able to get rid of this bug if I had to. Cos I had treated some people. So on that - and the other thing that I found out that year was that forty per cent of blood donors at Fremantle Hospital, at the Red Cross in Fremantle, had H. pylori, according to my serology, the blood tests I did. So they had antibodies against the bacteria, and I couldn’t believe it at first, but whenever I tested them they came up positive, when we did the endoscopy. So I said well hang on a minute, how can be that forty per cent of the population of Fremantle has it? They’re all Italians and Greeks et cetera, so that’s a hotspot for Helicobacter.
So I said, probably nothing's gonna happen when I take it. So I didn’t expect to get unwell, and I went ahead and did it. But also I did a careful study. I took a baseline sample and a biopsy showed that I didn’t have it. And so my colleagues were looking at the samples. I drank the bacteria. I recorded what was going on. And then we took the scope down a couple more times and took biopsies and showed that germs had infected. And it showed all these white cells invading my stomach and trying to eat the germs, eat the bacteria. So it couldn’t be psychosomatic. You couldn’t do that just by knowing about it or being frightened or stressed or something. So I said this is what you see in ulcer patients. And look, it’s happened in my stomach, except worse, during the acute infection. So, you know, I don’t know how I could produce white cells going to the lining of my stomach, eating the bacteria, unless the bacteria for harm were harmful, and that’s my immune system.

So it became a bit believable then. But the down side of this kind of thing is that, it was it was on Michael Moseley’s Medical Mavericks shows. And he would regurgitate some of the Helicobacter story. But one of the stories that is true is a guy called Max von Pettenkofer, and he was the Minister for Health in Germany, in charge of infectious disease in the 19th century. And so when Robert Koch discovered the cholera bacteria, and they said this is the germ that causes cholera, von Pettenkofer said it’s not true, it’s harmless, and to prove it, I’m gonna drink the bacteria. So he drank cholera bacteria out of, you know, somebody’s diarrhoea or something. Don’t ask me how he got it.

He drank the cholera bacteria, and he didn’t have an illness! We know now that not everyone with cholera dies from it or has is unwell. You know, a lot of people are asymptomatic. So he was asymptomatic, he published his research, told everybody in Germany they didn’t really need to worry about dirty water. Thousands of people probably died of cholera over the next ten years until they eventually said, you know, he’s just an old scientist, he doesn’t know what he’s talking about, he may be
Minister for Health but he’s hopeless. And everybody started having clean water after that.

Mm.

But for some years, a lot of people didn’t worry about dirty water because of Max von Pettenkofer’s self-experiment.

So did you know about that experiment before you did yours?

No, I didn’t know about it. Ha ha!

(laughs)

So I probably would have been very paranoid. I would have had to do it on myself several times. But after I did it, there was a doctor in New Zealand that did exactly the same thing.

Mm.

Got the same results.

With H. pylori?

Yes. Yes, and he couldn’t, he tried to treat himself - he couldn’t get rid of it for three years —

(gasps) Do you know who that was?

— so he was, he was unwell. He was...I can’t think of his name. He’s probably a professor now in Auckland of infectious disease.

I’ll look him up.

Yes.

You’ll probably pull him up on his web page.

Yes. Yes. It’s interesting. Why didn’t you – or maybe you did, I don’t know – why didn’t you do a study with more people in it? Or an experiment with more people in it?

Oh, the question was, would it be passed by the ethics committee?

Yes

So realistically. . .

(Laughs)

It would have taken me six months to be approved and, you know, I would have had to have funding from NHMRC.

Mm.

They hated my research, in those days. So I just needed to answer this question. So I had been talking about it, giving grand rounds about these bacteria and antibiotics. I hadn’t - I’d had no double blind study at that stage. I had no animal model. And so I didn’t really didn’t have a leg to stand on scientifically. So I said, am I going to spend the rest of my career trying to chase this ulcer bug, or is it really a commensal? So I have to just do the definitive experiment. So it’s a good example of testing your own hypothesis. So if you if you’ve got a new theory, you have to be prepared to do the experiment that’s going to prove that you are wrong. You pray that it’s not gonna work. You pray that you’re going to be right, but you actually have to test your own hypothesis. So say if so here I am, at the end of my
medical training. I’m going to go off into geriatrics or somewhere into private practice if nothing happens. If I get - if I develop gastritis as we would expect from what we know about this bug, then that’s where I’m going to go. I’m going to go into research and follow this up cos it’s too important to let it drop. So that little experiment I did, I was sitting at a junction in my career.

Mm.

I’m going to be a comfortable private practitioner whatever, or I’m going to be some masochistic researcher who is going to spend a lot of time trying to get papers published. A lot of suffering there.

Mm.

And so I took that avenue and it turned out okay. But it really - the first ten years was pretty tough. And it was tough on my family, on my colleagues. Because obviously if you, every time you see Barry getting rejected or failing at some project, you say, ‘oooh, you know, I feel for him, he’s such a nice guy’. (Laughs)

(laughs)

But I was loving it, so I like a good fight. (Laughs) So it never really bothered me.

No.

Because you only have to have one or two patients that you really make a difference to.

Mm.

And you say that didn’t happen by chance - I know that eventually I’m going to be out there and everyone’s going to say, ‘would you like to write the chapter in my textbook about ulcers?’
Mm.

And it’s going to be about these bacteria. So I then spent ten years writing chapters until I got burned out! And - well I don’t hate it, I still write chapters, but I have, I can tell you I’ve got several chapters I have to write, usually about the same thing.

Were you always a great communicator?

I think I was. I think I could always do an interesting interview. I must have some Italian blood in me I think. (Laughs)

(Laughs)

Actually, well, it’s a skill. I don’t necessarily know I could do it initially. But in the United States people who were in media... I never did any drama or acting, but people in media told me things, which I hadn’t realised before. And one of the things that you we should tell doctors is that you cannot speak with inflection in your voice if you keep your hands still. So if you put your hands under the table and don’t move them, your voice will be boring. But I learned very quickly that if you free up your hands to use a bit of, you know, gesturing during any kind of conversation, even if it’s a phone conversation, it’ll be ten times more interesting. And so, I someone did a practice run with me once on a talkback show, and told me that. And so then I was doing a call in talkback show on the radio so with Russell one of the talk time guys, as long as I’ve got my hands free I know I’ll sound interesting. But if I sit there with my hands in my pockets, I just become boring. And most doctors don’t realise that. A bit frightened of the cameras so they’re not moving, and they’ll talk away, and it’s just dead boring.

Yes - that’s a really interesting connection between the body and that physical expression.

Gotta get your hands out.

Yes.
Have them. And so often playing with something like having a pen, you know, holding something, it makes the interview much more interesting on camera. Even if your hands aren’t actually in the picture.

Mm. Yes, that’s a really good point. I think the same probably applies to when you give a public talk or a lecture.

That’s true. I can give a lecture anywhere and it sounds interesting. And it’s just because I know how to talk.

I wanted to ask you - we’ve talked a bit about people - well, you’ve spoken a bit about people writing to you, and it sounds as though the large bulk of that has been people with ulcers, or you know, someone with an ulcer --

Yes.

-- who’s concerned about the medical side of things. Do people write to you about other stuff or contact you about other things.

People with weird undiagnosed diseases often write to me.

(Laughs)

Saying ‘Dr Marshall can you do some research on this?’

Mm.

I say, well, I know of a, have a look on the National Institutes of Health research clinical trials research web page and see if you can find connect up with somebody there, cos at least they’ll know all about it. So usually these days you can find something on the Internet. No matter how rare your disease is you can find a club of really weird rare people that you can talk to. And then you never know. You might find out there are thousands of these people. So I s’pose things like autism, colitis, what’s the new one - Asperger’s syndrome I hear about.
Everywhere.

It’s because of that ABC show where that doctor’s got it and he’s horrible to his patients and they all love him. (Laughs) Every doctor’s dream! What is that called?

House?

No, it’s not - House is like that. Okay House is another version, but the English guy who lives in the country - he leaves London and goes to this real weird little fishing village.

Oh yes, yes! What’s his name, I can’t remember the name of the character.

(To assistant) Chris, who’s the character with Asperger’s syndrome?

Yes, I can’t think of it either. I know the show you’re talking about. Yes, yes.

He hates his patients and he’s always abusive to them.

Yes!

Every doctor’s dream. So I do a bit of that. I remember over the years someone’d come in and say well one of the interesting things about this Helicobacter is that men will get ulcers. It’s a male sort of disease. Cos they have a higher acid level and maybe they smoke more, was the other thing. And women with Helicobacter often would never have an ulcer. And so they’ve have a barium meal or investigations for the same, exactly the same symptoms. They’d feel nauseated, gnawing sensation et cetera, and they wouldn’t have an ulcer. They’d have no excuse for slacking off and not feeling well. And so they would get labelled as being psychoneurotic. So if you were a man with an ulcer, oh, you’re an ulcer personality, you’re under a lot of stress, you’re the money earner, all that good macho stuff. If you’re the same, if you’re this guy’s wife, you’re working twice as hard, with all these kids and your life is chaos, and you feeling sick, and you’ve felt sick since your age fifteen. You never
knew what was wrong with you, and nobody's got any sympathy. You're just mad; you're just on antidepressants or something. So I soon had a clientele of that sort of patient. So it was fun, actually, cos I saw, I was happy to do geriatrics, but I ended up with a lot of young women coming into my practice because they wanted to someone to have a look at them, and say, 'I'm sure there's something wrong with me. Dr Marshall, all my doctors just say I'm mad. What do you think?' I'd say 'well I think you're mad too, but let's do an endoscopy and see if you've got a germ in your stomach, because if you've got that, I couldn’t care if you're mad or not, I'll give you some antibiotics. I mean, I'm not a psychiatrist'. So I used to have fun sort of interacting with these women, and quite often they would have something genuinely wrong with them that had been missed. And if they were mad I'd say 'well look, you're fifty years old and you're mad, I'm not going to be able to fix you, get used to it'. (Laughs)

(Laughs)

You've coped for fifty years, probably you'll be okay for the next fifty. And I'm still have patients like that.

Yes.

So often you can't fix people. Can't fix everything.

No, and I s'pose you can't try to either.

So someone has a strange personality, well . . .

Mm.

You do your best. But you shouldn't be too depressed about not being able to cure them, because there’s so many things you can’t cure.

Mm. That sense of enjoyment you get from your work is really apparent --
Mm. Mm.

-- and I wondered if you could talk a bit about what makes you a good doctor. And what makes you a good medical researcher.

Well as I said I sort of steered away from those easy areas of medicine. Because I felt that it was maybe a bit too easy and a bit too the same. And I didn’t necessarily steer away deliberately away from general practice. But there were a few years in the seventies and early eighties I think where a lot of people who were smart found themselves in general practice and it was, it was becoming a bit boring. Every sore throat was the same, you know, and the government said you do this and this and write the prescription. And so what do you do with your life? You’re sitting there day after day doing the same thing. A lot of people became bored with general practice. So that’s what I would worry about. Of all the things I fear, is boredom.

Mm

And I will actually do something crazy or irritate somebody just to get some feedback. Just to get something interesting happening, some kind of interaction. So I get that from the patients and nothing makes me happier than having an incurable patient who sits there and tells me their life story for thirty minutes. I’m quite happy to listen to that. Maybe, maybe get involved with it vicariously.

(Laughs)

(Laughs)

So I have patients like that. And I will maybe get nowhere over, and I’m maybe an hour late in my clinic et cetera, but I’ll probably come home quite interested with some interesting details and quite a satisfied feeling after over the day’s work. so nothing’s more annoying to me however than sitting standing in a line because of some inefficiency, and there’s less of that in Australia now. But I can tell you over the last twenty years that there’s been a lot of that in Australia, and it’s because people, maybe people are not aware of what the international standard is. You don’t
necessarily have to invent reinvent the wheel on everything, and there’s some good things we do great in Western Australia, for instance, that maybe they don’t do in Melbourne or Sydney, or they do it differently. And you would say well they do it differently over there, and then you can say is it better or not? And you can make a decision. And so you can be independent over here and be a bit experimental.

Yes.

But you don’t want to be ‘this is how we do it here, and we don’t want to know about anything else’. So that attitude annoys me.

So it sounds as though you’re quite an open-minded inquisitive kind of a person really.

Right, I’ll be, I’ll look out for things that make anything more efficient.

Mm.

And so I’m always very interested in technology. I’d say that in, say in Australia or Western Australia, cell phones have probably doubled our productivity. Except if you’re in a trade. You know, if you were laying bricks or a carpenter or something like that, your cell phone will help, maybe you can find out where to go and get a saw blade without actually driving round to ten Bunnings-es till you find the one you want. So it helps everybody. But for academic pursuits and business and everything you can run your business in your car at home, all kinds of things. So I would say in medicine it’s the same. And I think ultimately people will just do more and more stuff on the Internet and over the phone. A lot of things you do, you could, you have an Internet doctor doing it for you.

Yes, for sure. It seems to have really changed the way we have our relationship with medicine.
Yes well I haven’t seen it being properly billed for in Australia. One of the things that I said to get anything new in health in Australia, you have to find some connection to the funding and the bureaucrat.

Mm.

They’re - every time he releases more funding, he gets demoted. He only gets promoted if he spends less. So, if you say, well I can, you know, a lot of people are calling up the hospital trying to find out about flu, why couldn’t you take their Medicare number and charge five dollars and then have a person who is occupied 24 hours a day just helping the community doing that. Well you can’t do it, because there’s no way of actually paying that person’s salary. You’ve gotta go begging to the health department or somewhere to do it. They’ll say we haven’t got enough nurses, you know, that type of thing. Whereas in the US, someone says there’s a need, I’m going to start it up and I’ll charge for it and it’ll be a business and everyone’ll say it’s great. And it happens twice as fast. So there’s ups and downsides of the way you organise your healthcare.

Yes, definitely. I’ve just got two more questions. The first one’s gone completely out of my head. So I’ll go with the second one. Which was about whether you have advice for young researchers following in your footsteps after everything you’ve learned about how systems work internationally and nationally, after all your experiences.

Okay. Well I learnt - there’s a few things I’ve learnt only gradually over the last few years. I would say try and do, you should do what you like. And there’s a number of reasons for this. If you don’t like it, you won’t be able to be good at it. You won’t put a hundred per cent effort into it. If someone else likes to do it, whatever it might be, they will put a hundred and ten per cent in it and you will never be competitive with that person. Whereas if you like to do something very weird or a bit strange or esoteric, I can think of a million projects in biology for instance or medicine that you could focus on, and everyone’d say well why do you want to do that? Well the answer is, if it interests you and it’s difficult, pretty soon you have no competition.
And before you realise it, you’re the world expert on it. So in medicine there are many disgusting areas of medicine that you could focus on! And I’m sure there’d be a disease somewhere that people would appreciate having some interest taken in. Actually one of my side projects for an example was bad breath.

(Laughs)

I had a lot of fun doing research into bad breath. I still do a little bit of it, but it’s not in the medical books. But for people who have chronic breath - halitosis, it ruins their life. You can’t be in sales. And it’s a big mystery. People really don’t understand it. So there were people in California who were interested in it. And there’s some bug that some germ that they’ve discovered and someone’s patented a treatment for it. That person will make millions. So how could you, you know, make a living out of bad breath? It’s there, there’s plenty of people who have it. So that would be one thing. So if it’s difficult and a bit rare but you enjoy doing it, that’s the perfect thing for you to do. Now what’s the other thing? The other thing I’d say - this is my new motto. There’s nothing worth doing that takes less than two years.

(Laughs)

So in my career everything, every project I think up, takes at least two years. If it’s a one year project, I probably it’s probably not worth it. There’s already a million people doing it. Cos a lot of a lot of things particularly in your academic career, they say right, you’re gonna do honours, or you’re gonna do masters, or you’re gonna do something. You know, you start on start February, you do a bit a couple of months planning, you get about three months of lab work for instance, and then you do the write up and then you have to finish it. And that’s - you go on to something else, it’s your holidays and you do something else the following year. So millions of little quick projects are being done, and often they, you know, things a bit significant need a bit of follow through. So even early in your career, probably you need to be in a two year time span early on. Cos if you’re like I was, I probably am still naturally I try to get things finished in a year. You cannot do it and it’s very frustrating. Especially if you’ve got ADHD --
Or creativity as I call it! You cannot finish anything. It’s great being a Nobel Prize winner cos then you can set up a team and you’ve got a lot of people trying to finish everything for you and, you know, get the best bang for the buck on the Nobel Prize for instance. But I have to say that early on in my career it was so frustrating, cos even when I discovered H. pylori I said, I suddenly realised this causes ulcers - what can I do? Bad luck, Barry, the deadline for grants was last week. I say well you know I can’t work on a deadline. I thought of this - I only thought of it this week. I didn’t know this a week ago. So why can’t I get funded tomorrow? Thousands of lives are at stake. You know, of course, as far as the government and the NHMRC and everybody’s concerned, that is irrelevant. We work on slow time periods. So you’ve gotta plan it for six months, find your collaborators, and then write your grant for six months, and then it’s ten months before you find out if you’ve got it. Or eight months or something. And then it kicks in the year after that. Kind of, oh my god. I could never do that. And so I have to tell you that my success in writing grants is very, very poor. I probably have a hit rate of about one in five. But luckily when I really needed one, when I was really desperate, I probably tried harder. So that you need to make - you don’t want to make them too easy, but at the moment I think it’s probably too difficult to get research grants.

Mm.

And people who are hopeless at writing grants like me don’t get them. And I dunno what they do. But they don’t get Nobel Prizes. Some of them do.

Some of them, not very many.

Yes. But maybe they are the ones that do get the Nobel Prizes because they go through another pathway.

Mm.
They'll find a short cut. And then they'll make the big discovery. So I made, I took many shortcuts and probably I took them because I wasn't funded. So in, you know we could say I've just suddenly had an inspiration. So I wasn't funded in the applications I put in at in 1983 because they were probably hopeless applications. I'd probably be rather ashamed if I read them now. So I was taking shortcuts and doing all kinds of other things, and one of the things I did was I drank the bacteria. I treated people who walked in my door, I gave them some antibiotics, I developed a blood test, developed some diagnostic tests. So I had about five research projects on the go, if it were - whereas if I was funded I would have had to come to work at you know 8am every morning and do - give people antibiotics for ulcers. And there were ten other angles I would have had to ignore. So in conclusion the best thing that ever happened to me was I didn't get a research grant in 1983. It's probably true.

You've just reminded me of a guy Doug Prasher – he was in the group of scientists who worked on the fluorescing gene amongst jellyfish.

Oh yes.

And he is the poor sod who kind of ran out of post doc funding and dropped out of science and ended up driving a shuttle bus for a car company in somewhere, deep south America. And his research is incredibly important research that he'd done that he hadn't managed to keep going with --

Yes.

-- he gave it to some colleagues and they went on to win the Nobel Prize. And he didn't get the Nobel Prize. And I just thought, you know...

Ooh. Well actually!

It's interesting that you didn't end up like that!
Well I’ll tell you a sad story. It’s not for me. But Chris have we got a Helicobacter book here somewhere? Pioneers book?

Yes. It’s just in that cupboard there, Barry, it’s there or the one beside it.

(Barry finds the book) Have you seen it?

No

Helicobacter Pioneers. So I’ve been hearing these sad stories over and over again. We’re down to our last few copies so I won’t sign it, and I’ll just loan it to you!

Okay.

Then you can read it. But I collected all these stories of these poor people who discovered Helicobacter. And the one that is in there is this poor Greek physician who discovered that ulcers were cured by antibiotics in the sixties. So he didn’t have any technology, couldn’t prove it. He just treated thousands of people with ulcers with antibiotics. What happened to him? They struck him off the register, they deregistered him in Athens because he was, you know, going against the tide and it was not dogma, the dogma said other things. He wrote a paper that was rejected by the JAMA, which is the big US journal. He wrote a patent, which was granted in Greece but he didn’t have the resources to do anything else. And then about ten years later he died. He wasn’t totally penniless but, and he was still running a secret, illegal practice on the side I think! But you know. It’ll make you cry when you read that chapter. Pass it and I’ll open that chapter for you. If that’s the only one you read, that’d be the one. Likoudis... It was about 1962. That’s him - John Likoudis, general practitioner in Greece who in 1958 discovered the aetiology of and the treatment for peptic ulcer disease. If he had had the right resources and if he was in, say, if he lived near the Mayo Clinic or someone, they would have discovered the cause of ulcers about five years later and he would’ve won the Nobel Prize twenty years ago.

Yes.
But actually there were a lot of people before him that missed out as well.

Yes. It’s fascinating isn’t it - the timing and the resourcing. But you mentioned the reaction of the scientific community and that was what my missing question was about. That sense of struggle for ten years.

Right.

Going, you know, swimming against the stream. Failing...

So you can say, well as a scientist or a doctor, you can be confident that eventually the truth will come out, and if it’s, if it really is a cure for cancer, one day there’ll be a knock on my door, and a drug rep’ll come through the door with a glossy brochure and a and some samples. At that point in time I’m obliged to pay attention to it. But there’s something on the news every day about some little slimy little bug that cures cancer.

Mm.

Or something. A new herb or something. So you can’t possibly be an expert on every single one of those, so you have to trust in the system to a certain degree. However, if it’s a common disease, and the treatment is something that you’ve got in your drawer, amoxicillin samples for instance, a lot of people will have a go at it if they hear about it. So that’s where the media is connected.

Mm.

And thousands of doctors were testing out my treatment. And they’d typically test it out on their wives and mother in laws. And say, god, my mother in law, she was so cranky until I gave her some amoxicillin. She says her appetite improved, her, and she’s been a saint ever since. You know, that kind of story would come back. So the media did that. So that I had a following long before it was accepted dogma by doctors. And plenty of patients would have turned up at their doctor’s practice with the news article, and said I’d really like you to try this on me. And say (grouchy
doctor voice) ‘that’s rubbish, I’m not gonna try that on you, you have to go to someone else.’ Well, pretty soon the doctor in that town who did treat H. pylori had 95% of the patients. Um. I’ve got a great story - the first lecture I ever gave in New York City was 1987. So I arrived in the US, lo and behold, someone asks me to come up to New York City and give grand rounds. So I gave grand rounds. And there was a doctor there and he was, it was the day before he left and went into private practice as a gastroenterologist. And he went up into Connecticut. And I met him ten years later, he said ‘Barry I’ve got the biggest practice in Connecticut, cos the day after I went to your talk, you told us about this little test that had been discovered and was being made in Western Australia, and I mail-ordered it, and I wished to receive it in brown paper parcels because it was illegal to import it.’ And he was started using it up in Connecticut. And all these ulcer patients from miles around plus their wives who had dyspepsia and their you know mothers in law and everybody were all turning up. And so if he was on easy street - he probably drove a Rolls Royce and had six partners and things. He’s probably retired now. Probably lives in the Bahamas.

All because of the brown paper bags.

Yes. Just all because he happened to go to my lecture and was convinced. He’s or at least he said ‘you know I should try that, it might be true.’ And so doctors that did that were actually very successful. And everybody who worked for me in the US ended up having a great practice because they got in on the on the crest of the wave with the Helicobacter.

Yes.

And quite often there were big group practices, and they would say well this is interesting, why don’t we hire this guy and get him as a new partner. Because this appears to be an exciting area. So that these guys would then come in, and you would wonder why it’s not why it’s difficult to stay in hospital practice, in university practice in the US. My fellows, well they’re registrars in Australia, the
gastroenterology fellows, would leave and go straight into $250,000 salaries in private practice. If they were - they’d have to be good.

Mm.

You know, they were pretty sharp, most of them. But of course they had to - they owed a hundred thousand dollars for their university degree, the debt from university, and had postponed their life for ten years at that stage and, but it’d only be a couple of years and they’d be building a mansion and having a nice car and all that kind of stuff. So that was secondarily rewarding for me to see that happen.

Yes, sure. But it’s just interesting hearing you talk about it, that that undercurrent of people early adopters, people hearing about it, trying it, having a go.

So early on, they would always delegate the Helicobacter research to the most hopeless, junior, unfunded doctor, from Timbuktul or somewhere! And then a year later they’d notice that he was, he’d published a little paper, he’d be getting invited to speak at important lectures and conferences et cetera. And all those guys are now all the big professors in the United States. So if you go, if I go to the US now, I’m, I’ll be invited to black tie dinner, because the deans and the chiefs of gastroenterology are all these people who were in the controversial Helicobacter research fifteen years ago. Twenty years ago now. And now they’re all the professors of medicine!

So sometimes the risk of playing in an area that’s unaccepted is definitely pays off.

Yes the other thing you need to realise is that, this is probably one of my third lessons is that a lot of these things we know in medicine are really like a religion. So you get them taught in medical school, it’s a tradition, there may be some partial factual basis or database to it. But a lot of it’s beliefs. And so you have to realise it’s like a religion. You can come in with new information and people just don’t feel comfortable with it. They don’t have the right gut feeling, it doesn’t mesh with their belief - obviously with ulcers there were about twenty other areas that you would
have which were related to ulcers. And your whole understanding of gastroenterology would be based on stress.

Mm.

And you’d manage all your patients perhaps quite successfully like that. So you can’t just throw that out. This is my life’s work, I’ll just chuck it out now, I’m just the same as a medical student starting from scratch. So it’s important to be a bit patient, because people who start the new, take on the new technology or the new paradigm, ten years from now they’re all in the universities as lecturers. And they’re giving the lectures out to the medical students. And twenty years from now they’re the head of departments. They’re the professors. So if you say your career starts in specialist medicine when you’re thirty, well then when you’re forty you’re the young turk if you like. And you’re running around on the lecture circuit, all that exciting stuff’s happening, and if you put on a good show, you’ll be then invited to interview for the new chief of medicine job. So when you’re 45, you are the hot new chief of medicine at the University of Virginia or Harvard or somewhere. So those years’ll go by relatively quickly once you get in the system and you’re quite busy. And then it changes. And so why did it change? How come everybody suddenly believes me? Well, Barry, because these guys who are running the medical schools are now your mates. And you are just as old as those professors used to be when nobody believed you. So they didn’t change their minds, they retired.

Yes.

And now they’re out there, and they probably still don’t really believe it!

Yes. This new fangled Helicobacter treatment!

Yes. Oh, yes! (fogey professor voice) ‘So Dr Marshall so some ulcers are not caused by stress? That’s a pretty weird concept.’ Well, not exactly. Let me just put it this way. Hardly any ulcers are not caused by stress. Nearly all ulcers are caused by Helicobacter. (Makes fogey-voice dubious laugh) Never. No one’ll ever believe that. And so of course I used to get into these big arguments in conferences and ram it
down their throats. And some people would be not too happy. So I could have been more diplomatic on a lot of occasions!

(Laughs)

I probably did myself made it harder for myself at times. The media lesson I learnt, if there’s no controversy, there’s no news. So now Helicobacter is not really news because people believe it. As soon as believed it, I was sort of like, whoa, this is pretty boring, where are we gonna go now? What am I gonna do for the rest of my life?

Yes.

So you know. That’s a big problem.

You’ll have to sit on your laurels. Or your laureates, depending . . .

Yes, so you have to come up with some kind of new controversy so we’ve been --

Hard at work!

We’ve been fanning the flames.

So what’s next? What new controversies?

Well. You know, how many years, how long have humans had it? I could do that... if so many, half the world’s infected with Helicobacter, and they have been infected for a hundred thousand years, it must be doing you some good. Otherwise we all would have died out. So what’s the answer? How does it do you good? What use is it? And then, so Dr Blaser in the US finds out that children with Helicobacter have thirty percent less asthma.

Oh.
Oh! So it’s good to be a little bit unclean and have infectious germs and things on you, cos otherwise you have, your immune system’s too hyperactive and you’re getting allergies. Plus god only knows what else. So, what are you doing now, Dr Marshall? Well, I’m not curing it anymore, I’m giving it to people to drink. So that should raise a bit of a stir. That’s true.
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