SUE STOCKLMAYER, MIKE GORE AND CHRIS BRYANT

INTRODUCTION AND OVERVIEW

It is widely accepted that the importance of the communication of science to the public can be summarised under five headings. They are, not necessarily in the order of importance, economic, utilitarian, democratic, cultural and social.

The economic imperative, regrettably, is today the main driving force towards a better scientifically educated public. No better illustration of this is the joint statement of March 2000 that President Clinton and Prime Minister Blair saw fit to utter, that the human genome is the common property of humanity and not the intellectual property of a few entrepreneurial commercial companies. The concept of intellectual property, however, has fuelled many of the arguments in favour of public awareness of science. This is implicit in the Clinton statement that stresses the attainment of national goals.

The utilitarian argument is closely allied to the economic one. It is the view that the public should be scientifically aware because of the way the community uses science. It is often stated that science in everyday life is invisible, taken for granted. And so it is and–probably–so it should be. It is not necessary in everyday life to know how a magnetron works to run a microwave oven, nor much about electricity to be able to switch the light on and off. It is, however, desirable for the public to keep abreast of the general developments in science becoming aware of new applications, such as the use of DNA fingerprinting in identifying criminals, and feeling comfortable with them.

In a sense, the democratic argument is a subset of the utilitarian argument. The general public is often asked to make decisions about new technologies that could have far reaching effects, both on its own wellbeing and on the rest of the world. Trading in carbon futures in an attempt to halt global warming is an example.

Unfortunately, few politicians or financial experts have any scientific training at all. If the expertise is not present at the highest levels where does it reside? The answer is that it has to reside with the community that, through the exercise of democratic rights, appoints the politicians. It is not just wishful thinking to imagine that, eventually, political will, as expressed by scientifically aware politicians, will have an influence on multinational corporations.

Next, there is the cultural argument. Science is one of the things people do and, like all of the things that people do, it can be done at the highest or the lowest level. As Stephen J. Gould has remarked, the best science is like high art, worth appreciating for its own sake and not necessarily because it brings an immediate benefit in material terms to the beholder. The elegant simplicity of Nobel laureate Niko Tinbergen's studies of digger wasps and herring gulls had no immediate 'use', but for the reader the sheer pleasure of comprehending something of the life of these common animals transcends the need for 'usefulness'. Although a lesser scientist might have achieved the same results, Tinbergen's insight, the creativity of his hypotheses, the elegance of his experiments and the simplicity of his writing combined to produce work that takes science to the highest levels of human endeavour. Mathematicians experience the same *frisson* of pleasure when contemplating an elegant solution to a problem even though a 'quick and dirty' answer might do the job.

Finally, there is the social argument. As science permeates all levels of human activity then an awareness of the basis of science and the issues surrounding it will serve to enhance social cohesion. Much of science has relevance for all cultures and becomes a shared tradition. Unfortunately, it cannot be denied that, as Gregory and Miller (1998) point out

> There is no doubt that many in the scientific community who want to further the public understanding of science are really concerned with increasing the public's appreciation of science, with a view to enhancing the status of themselves and their colleagues. (p9)

Scientists are very likely to think in terms of the way they perceive that scientific communication might benefit their own work. A common feeling amongst scientists, as soon as they emerge from the self-delusion of believing that people will not understand what they do, is

> if only people knew how exciting my science is they'd give us more money

In spite of much evidence to the contrary, they rarely think

> if people knew what we are really up to, they might stop us

Scientists are no more nor no less altruistic than non-scientists. Even men like Humphrey Davy, Michael Faraday and Thomas Huxley, all of whom were outstanding science communicators, were driven by the twin imperatives of the science itself and the need to make a living. Good communication was therefore essential.

As far as the community is concerned, science is invisible until such time as it has a need for it. It is the task of the science communicator to demonstrate to the community that it has such a need. When the need is recognised the rate at which non-scientific members of the community are capable of assimilating scientific ideas is often astonishing.

There have been many surveys that claim that the public would prefer to read about science ahead of sport in the newspapers. They are often cited as a validation for the science communicator and one that should convince editors to include much more science in their papers. The editors, who presumably know what sells newspapers, remain unconvinced, and so does Professor Doherty (see Epilogue).

Yet it is an inescapable fact that several surveys have come up with the same conclusion. The reading public likes to read about science and places it high on their list of priorities. Editorial policy, however, is informed by circulation. It is clear that editors are comfortable with the view that, while the reading population might like to read about science it doesn't want to read about it too much.

In understanding the community's attitudes to science, it is necessary to distinguish between 'knowledge' of science and 'affect' or mental disposition towards science. Herein lies the dichotomy between the public understanding of science (which rejoices in the revolting short form PUS; as someone remarked, only scientists would come up with an acronym like that) and public awareness of science.

It is good to be sceptical of studies that indicate that the public has a poor grasp of science. Many of these studies contain the seeds of self-fulfilling prophecy. For example, Durant Evans & Thomas (1989) describe work in which general scientific knowledge questions are asked of a randomly selected sample of people. This necessarily constructs an image of a public that is deficient in its understanding of science. Only if everyone answered all questions correctly could this deficit model be challenged. Other studies may have other flaws; if the public is asked what it wants to read about in newspapers, it may give 'science' as the socially desirable answer, or confuse science with medical breakthroughs. If the community is asked whether it is proud of the achievements of its scientists it might answer 'yes' without having a clear idea of exactly why. We can all be proud of the Dohertys and the Floreys without necessarily understanding what they did to win the Nobel Prize.

Only when the public have a specific interest will they turn to the science pages. When they are personally engaged, they will read voraciously and be capable of mastering difficult material with ease. It is the task of the science communicator to increase the 'need to know' and nurture it.

This seems so obvious that it is a surprise when scientists fail to grasp this very simple idea. In the face of declining enrolments in science at secondary and tertiary levels in the western world, and of the obvious disenchantment of young women with science, there is still great resistance amongst scientists to making their work accessible.

Research Councils now include the concept of 'duty' in their instructions to applicants. The Particle Physics and Astronomy Research Council in Britain, for example, states that

> We believe that all those engaged in publicly funded research have a duty to explain their work to the general public.

This imperative generates both anger and anxiety among scientists when confronted with it. One of us (CB), in an earlier incarnation, recalls the intense irritation he felt when he had to spend valuable research time on both grant applications and communication with the public. These are feelings shared by many scientists today. We frequently run short, 3-day workshops on science communication for scientists. We have noticed marked variations in response to our opening question 'why bother with science communication?'

The more senior scientists tend to express resentment. They are in denial–their position is summarised by this statement:

> people don't need to know about science. They should just let us get on with the job.

When we argue strongly that the community needs to become more scientifically there is a subtle shift of position:

> I'm a scientist. It's what I do best. Let other people do the communicating.

Their point of view is easily understood. They grew up in a world of certainties, entrained into science at an early age, secure in the knowledge that there were facts somewhere 'out there' to be discovered and that, once discovered, these facts would immediately be accepted by an admiring public. They were never expected to communicate and may even have gone into science because they were poor communicators.

The ideas that science is culturally dependent, that knowledge is constructed, threaten their mastery of their discipline. They feel uncomfortable, unhappy and yearn for the certainties and security of their laboratories and their white coats. From this position it is a short step to agreement that while science communication might be a good thing it is not for them because

> people wouldn't understand what I'm doing.

The sub-text is that their science is so complex and they have invested so many years in acquiring their expert status that they find it difficult to imagine that it can be understood by someone who has not put in the same effort. It threatens both their standing with their colleagues and their self-respect.

This idea that their science might be accessible to a lay public is abhorrent to many western scientists who seek certainty and absolute truth. Theirs is a view akin to those of the mediaeval guilds that protected their knowledge by allowing only initiates into full understanding of the one truth. Knowledge was power and was not to be let go; its communication was only permitted between initiates. It often required special language and signs; and it was not for the general public.

Graduate students and newly fledged scientists do not hold these views so rigidly. They are still only on the verge of disenchantment and have largely retained their enthusiasm for their subject and even some proselytising zeal. It is imperative that this be nurtured.

In summary, increasing the public understanding of science is a worthwhile endeavour that creates an intelligent, informed and skilled group within the community. Such a group is an extremely valuable resource for the community. Increasing public *awareness* of science, however, is a longer term project, but one that, if successful, can contribute enormously to social well-being as it creates a community that is confident in its possession of scientific ideas and is comfortable about raising children to have the same confidence.

It is the intent of *Science Communication in Theory and Practice* to range far across the whole field of science communication. It gives both a theoretical basis for the newly emerging discipline and a series of personal histories, the authors of which are effectively saying 'this is what *we* did' and in all cases, they did it very successfully. They are offering their experience but none of them is prescriptively saying 'this is what you should do'. What they hope is that the prospective science communicator will shop amongst them and use whatever is fitting for his or her circumstances.

The structure of the book may need some explanation. It falls naturally into four parts, and an Epilogue. Part 1 consists of five chapters that are concerned with the disciplinary basis of science communication. Susan Stocklmayer explores images of science together with the implications they have for the effective communication of science. She dissects gender issues and draws attention to the 'masculinity' of science–the majority of practitioners are male, and thus are poor role models for girls. She points to the gender bias of texts, and dismisses biological factors as the prime determinant. She describes a constructivist model for learning and considers the consequences this has for communication. Glen Aikenhead sees science as culture, and the interaction of this culture with the 'culture of a public immersed in their everyday lives' is the essence of science communication. Science communication is 'crossing the border' and, when those borders are not crossed successfully confusion reigns. One of the editors still recalls with discomfort the debilitating gastric overload when the politeness, acquired as a child, of 'finishing everything on your plate' clashed with the politeness and generosity of his Indian hosts, to whom an empty plate meant 'please may I have some more'. Overloads are often experienced during the process of communicating science and, because most people are polite and have no wish to hurt feelings, the mores of the two cultures are not explored. Science communication permits an unthreatening exploration of the two cultures.

Jon Turney examines the depiction of science in literature, and science communication as a genre in its own right, and reflects on what qualities are present in good popular science writing. As the genre draws its inspiration from such a wide range of human endeavour he wonders whether it will ever be possible to categorise it. Lawrence Prelli sees science as discourse and discusses the implications of rhetorical understanding of argumentation in science, and the implications for scientific literacy. He has some trenchant comments on the science literacy movements –

> if the public cannot grasp these essentials (a majority of Americans in one survey believe that Israel is an Arab nation) why should we expect that science literacy campaigns can elevate their comprehension of the complex principles of science?

These prophetic words have recently been echoed by an influential report of the House of Lords who wish to move the game from 'public understanding' to 'awareness' of science.

Richard Eckersley takes a *fin de siécle* look at science and sees harbingers for the loss of confidence in modern science at the beginning of the last century. He finds science at a threshold of opportunity provided by science communication. It remains to be seen whether the opportunity will be seized; already the first

SUSAN M. STOCKLMAYER

1. THE BACKGROUND TO EFFECTIVE SCIENCE COMMUNICATION WITH THE PUBLIC

1. INTRODUCTION

To be effective with any audience, communication must be an interactive process. As Sless and Shrensky show in Chapter 6, science communicators who think only of the message and not of the 'audience' are likely to fail. Communication is essentially as much a matter of listening as it is of talking and, to be effective, each party must have some understanding of the other. In this chapter, I shall review what we know about the ways in which the general public views science and scientists and I shall consider some impediments to understanding which, if overlooked, may prevent effective scientific communication.

There is no doubt that communicating science is difficult. Were this not so, there would be no need for any of the chapters in this book. Indeed, there would be no one to write them! All of the authors are in the business of trying to make science more understandable. This chapter is about the public perceptions of science, and so we must immediately make some assumptions about the people we are addressing.

Let us assume, for the moment, that the 'public' is a Western group of people of various socio-economic and cultural backgrounds. This public is male and female, with all the complexities of personality, age and experience now embraced by the term 'gender'. The public has, on the whole, some rudimentary education in science. We know immediately that the form and extent of this education is country-dependent. Some (often female) have had some biology lessons but little or no physics and chemistry. Many remember little of their school science. Most have little knowledge of the earth sciences and most are increasingly conscious of ethical, ecological and environmental issues. The structure of this public looks immensely complex and variable.

Why, then, does world-wide research in the Western world - and in many Asian countries formerly occupied by colonial powers - keep finding the same overall picture? For the past twenty years at least, research coming from the area of science education has revealed a public that is fearful, mistrustful and ignorant of simple scientific principles. Why has education failed to address these problems and what should science communicators know in order to be more effective?

The research spanning two decades is immense. It encompasses the ways in which people learn, how and why people change their ideas, the nature of schooling itself. The theory of 'constructivism' has illuminated some of the reasons why people choose not to pursue science and fail to remember what they have learned - but that is not the whole answer. We know, for example, that part of the problem is

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that women relate to science less well than men and that science careers are less common amongst disadvantaged groups. It is important also to recognise that science is not "common sense" and that misconceptions abound. This chapter will review only those areas of research which relate directly to the informal learning of science. It is not possible here to address the problems of curricular structure and the nature of schooling. These have, in any case, been addressed at length elsewhere (see, for example, Cobern, 1998). To begin, let us examine the image of science and scientists as revealed by countless participants in the 'Draw-a-Scientist' test.

2. THE POPULAR IMAGE OF SCIENCE

The 'Draw-a-Scientist' test was devised by Chambers (1983) to investigate how children imagined a scientist. Not surprisingly, the most common image is of a middle-aged white male wearing glasses and a white coat. He frequently has facial hair and is often bald on top. He is surrounded by symbols of science that are usually chemistry apparatus - test tubes, flasks and so on. Since the early 1980s the test has been repeated all round the world for various purposes and with varying degrees of criticism as to its validity and meaning (for example: Butler Kahle, 1987; Finson, Beaver and Cramond, 1995; Lannes, Flavoni & De Meis, 1998; Jarvis, 1996; McAdam, 1990; Schibeci, 1986). The test is, according to many critics, flawed in that it encourages participants to perpetuate a ubiquitous media image of scientists - either the stereotypical mad professor of the movies or the friendly adviser who is advertising the most suitable washing powder. There is, without doubt, some substance to this criticism and if all were well elsewhere in the world of science communication we might ignore this phenomenon.

There is a darker side to this image, however, which we need to note. Very often, the drawings depict eccentricity bordering on madness, with an indication of evil intent. The drawings produced by female senior high school students (Figure 1) illustrate this inherent lack of responsibility towards humanity, and attendant cruelty to animals. It is not just *scientists*, therefore, who are depicted in this way – it is *science itself*. Whatever its origins – and one might conjecture that the stereotype goes back all the way to Dr Frankenstein and beyond (Turney, 1998 - it illustrates the underlying beliefs of the general public about who scientists are and what they are about. They are white middle-to-upper-class males, middle-aged, socially inept, at best eccentric and at worst downright evil. The nutty professor images portrayed by so many television science presenters merely confirm what everyone believes.

Can the 'Draw-a-Scientist' test be taken too far, and too much concluded from its results? Let us examine in some detail what it says about science. First and most obvious, science is seen as masculine. This masculine nature of all science, especially the physical sciences, has been much documented but is still hotly debated by many within science and outside it. As a 'seeking after truth', say the critics, how can science have any sort of gendered identity? Yet, as Fox Keller (1985, p.55) explains, members of the Royal Society of the 17^{th} Century which formed the foundation of Western Science explicitly stated that their science was

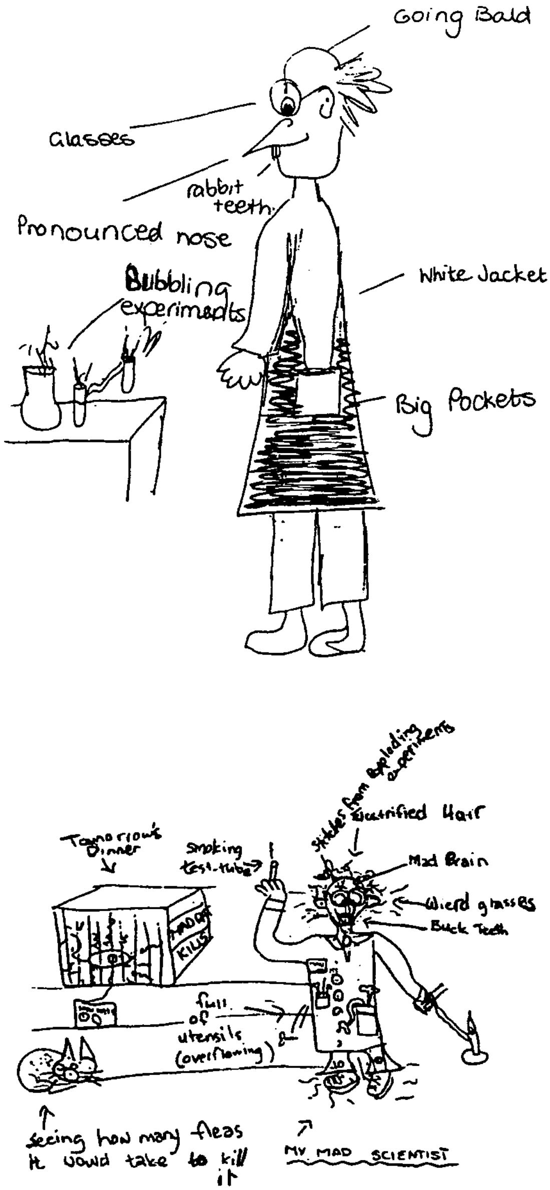

Figure 1. Drawings of scientists by 17 year-old female science students in Australia

'masculine and durable', seeking to capture and control a 'female' Nature in ways not hitherto sought. Their science was founded on virtues of objectivity, strength and rigor. It therefore sought truth in a particular 'value-free' way, asking particular questions which were decided and defined by its practitioners. Other, perhaps equally legitimate questions, were never raised because they were of no importance to the scientists themselves.

It is easy to see that the history of science is male-dominated. For all sorts of reasons, few women participated in its endeavours. Passing quickly to the end of the 20th Century, however, we find superficially a very different picture. Western Science is now perceived by many – including large numbers of university students - to offer equal opportunities to women and men and equal voices in the world of science.

> Things have changed since the beginning of science and if too much emphasis is put on encouraging females to take part in science, it could end up by disadvantaging males. (Female Australian science student, 1998)

> Science has not been equally accessible for women until recently... Now there is no difference. Women have the same opportunities as men and should take full advantage of them. I believe there are only men in the top positions because women haven't had enough time to occupy those places. (Male Australian science student, 1998)

Has the picture really changed that much? Kelly (1985) outlined four senses in which science might be described as masculine. The first was in terms of numbers–those who practise it are mainly male. At the end of the 20th century, the numbers have certainly changed in many countries at the school and undergraduate levels. A closer look at the distribution of male and female participants, however, indicates that the biggest increase in female students has occurred in the biological and environmental sciences with the physical and earth sciences lagging far behind. For example, in Australia at least, female participation in undergraduate engineering appears to have reached a plateau at 14%. As one goes higher up the scale of all science careers, the proportions alter dramatically in favour of males.

This bias is less true, however, of many European and Asian countries in which women reportedly form a much higher percentage of the scientific workforce. So perhaps the relative numbers are a cultural rather than a scientific issue, requiring specific initiatives in English-speaking countries to coax more women into taking up long-term careers? This may be true. We need, however, to look at how 'science' is described in some of these countries and what work is defined as 'scientific' before reaching a conclusion (see, for example, Ancog, 1998; Hermawati, 1998.) There is evidence also that despite improved participation rates, women in European science still struggle for equality of opportunity.

Kelly's second area of masculinity was in the packaging of science. She quoted science curricula, textbooks, applications and so on as coming from a male world and describing a male world. By 2000, much had been done to address this issue. Yet an examination of current popular physics texts reveals an overwhelming bias in favour of masculine examples. Those few that feature women are often stereotypical. The textbooks are still, in graphics and language, presenting to a male audience.

The language of science is an area that has attracted considerable criticism. Jargon is endemic in all disciplines but the language of science is *itself* inherently masculine. There has been a move in recent years to re-write texts to be more gender inclusive, including more examples of a 'gender neutral' type. Research into this issue indicates, however, that so-called gender neutral nouns ('an athlete', 'a builder', 'a cyclist') are assumed by female readers of science texts to be male. From my own observation, when a group of 14-year old girls were given a physics problem involving a bird, it evoked responses from all 30 students which referred to the bird as 'he'. Reasons for this are not well understood – but truly gender inclusive terms have been shown to be 'you', 'we', or examples of particular people by name, irrespective of their sex.

Kelly's third area of masculinity was that of practice. Those who instruct students, from school through to postgraduate study, set benchmarks of 'good' and 'bad' science, act as role models and define what science expects of its practitioners:

> Do they praise the loudest 'pops' when children are making hydrogen or the most beautiful soap bubbles? These seemingly insignificant choices set the tone of the lessons and influence the image of science presented to the class as harmful or caring. (Small, 1984, p. 30)

Last, Kelly quoted biological factors. Many of these have largely now been refuted. There is still debate, however, about the differences inherent in male and female brains (e.g. Moir and Moir, 1998). What these differences are is not yet well understood, but the evidence from the world of science is clear. Science is, at present, unappealing to most women and to many men. Its masculine character has developed as a social construction reflecting a patriarchal society. There are many examples, historically and at the present time, of overtly male practices and discrimination in science. The more subtle question of the nature of science itself has, however, also been explored, by feminist scholars such as Belenky, Clinchy, Goldberger and Tarule (1986) who describe 'women's ways of knowing' quite different from those of men. Women, according to these scholars, prefer amongst other things to consider problems holistically. They value intuition and prefer non-hierarchical interactions.

This presents a problem for science if it is still to be regarded as intrinsically objective, abstract and value-free. The sad result will be that it will always remain the domain of a few men of a particular type. The importance of factors such as intuition will continue to be denied, even though it is well established that, in the actual practising world of science, researchers frequently follow their instincts. Indeed, Fensham (1993) reports that a series of British television interviews over seventeen years with Nobel scientists revealed that although six laureates denied the existence of scientific intuition and five were doubtful, the remaining seventy two of those interviewed 'readily acknowledged its existence' (p.16). Fensham goes on to comment that 'the eleven (denials and doubters) then went on to refer to experiences of the same kind as the seventy-two'.

G.S. AIKENHEAD

2. SCIENCE COMMUNICATION WITH THE PUBLIC: A CROSS-CULTURAL EVENT

1. INTRODUCTION

Scientist denies cancer cure quote May 8, 1998.

NEW YORK (AP) Nobel laureate James Watson denies telling a reporter a researcher whose experiments have rid mice of malignant tumors 'is going to cure cancer in two years.'
Watson, co-discoverer of the structure of DNA, was quoted as having made that prediction in a front-page story in Sunday's New York Times...
Watson, in a letter to the editor published in Thursday's Times, said he told Times science writer Gina Kolata at a dinner party six weeks ago that the drugs, endostatin and angiostatin, 'should be in the National Cancer Institute trials by the end of this year and that we would know, about one year after that, whether they were effective.'
Times spokesperson, Lisa Carparelli said, 'We're confident of the story we ran and don't wish to be in a position of quarrelling with a respected source and authority. We're glad we were able to let Dr. Watson further explain his view.'

This miscommunication between Watson and Kolata probably reflects differences between the community of scientists and the community of journalists. Key differences between the two cultures may have been veiled by the fact that both people spoke English, a language in which terms or phrases have multiple meanings and shift their meanings from context to context. Thus, an expression uttered in the context of scientists talking among themselves may have quite a different meaning on the front page of the New York Times. Perhaps both Watson and Kolata overlooked the cultural differences that defined their two communities.

This chapter focuses on the communication between different cultures, particularly between the culture of science and the culture of a public immersed in their everyday lives. Cultural anthropology suggests that science communication with the public is a cross-cultural event. If people do not clearly identify the cultures involved in the act of communicating, people risk the quagmire of miscommunication. A critical analytic understanding of the culture of Western science, and of the cultures of various audiences, is a prerequisite to effective science communication with the public. In the first part of this chapter, I summarise this prerequisite to effective communication, while in the second part, I describe effective communication in terms of culture brokering, illustrated in part by a case study of a recent Canadian science centre exhibit.

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2. A CULTURAL PERSPECTIVE ON WESTERN SCIENCE

Before we can think about the cultural aspects of science communication with the public, we first need to clarify what cultures and subcultures are. Then we need to understand how people cross cultural borders to communicate with each other. Last, we need to become conversant with anthropological research into the ease with which people cross cultural borders. In this section, I develop several key anthropological concepts that are applicable to the realm of science communication with the public.

2.1 Culture

Cultural anthropologists such as Geertz (1973, p. 5) have defined culture as

> an ordered system of meanings and symbols, in terms of which social interaction takes place.

This statement accurately describes the scientific community engaged in research, as scientists develop more accurate and sophisticated systems of meanings (theories, models, laws and principles, often expressed symbolically), and as they publish their manuscripts in journals (formal social interaction) to establish the validity of their ordered system of meanings. In addition to communicating through formal publications, social interactions take place in person, by e-mail, by telephone, at conferences, in the lab, in the field, and in bars or at other informal gatherings. According to Geertz's definition, science can be thought of as a culture with its own language and conventional ways of communicating for the purpose of social interaction within the community of scientists.

In an anthropological study of a high-energy physics community, Traweek (1992) described culture in a more detailed way:

> A community is a group of people with a shared past, with ways of recognizing and displaying their differences from other groups, and expectations for a shared future. Their culture is the ways, the strategies they recognize and use and invent for making sense, from common sense to disputes, from teaching to learning, it is also their ways of making things and making use of them (pp. 437-438, italics in the original).

By treating physicists as working within cultural borders, Traweek discovered some fascinating behaviour and bizarre communication by Japanese high-energy physicists as they negotiated between the subculture of their Japanese national physics community and the subculture of the international physics community. Traweek found that risk taking, power, culture, and subjectivity were all intermingled in ways that encouraged Japanese physicists to conform with their Japanese national physics community. This made it difficult for these Japanese physicists to cross the cultural border into the international community of high-energy physics. Japanese physicists were the target of pejorative humour, sarcasm, and cultural reprisals from their Japanese colleagues. Therefore, Japanese high-energy physicists had to cross into the culture of international physics with great care and subtlety by using humour, selected conformity and politics, so as not to offend their Japanese colleagues in high-energy physics. By recognising the cultural differences between Japanese high-energy physicists and international high-energy physicists, Traweek could better understand the otherwise bizarre communication among some Japanese physicists. Perhaps there is a lesson here for James Watson and Gina Kolata - they should have recognised science as a culture, a culture with borders that must be crossed if outsiders are to understand the communication conventions of that culture, and if insiders are going to communicate effectively with the public.

Consistent with both Geertz's and Traweek's definitions of culture, Phelan, Davidson and Cao (1991) suggested that culture be conceptualised as the

> norms, values, beliefs, expectations, and conventional actions of a group. (p. 228)

This cogent definition helps to clarify how science is a cultural phenomenon. Science content can be subsumed under 'beliefs'. The communication conventions of scientists are guided by the norms, values, and expectations of the culture of science, and by the specific norms, values, and expectations of the specialty field of the scientist, that is, the his or her paradigm or scientific subculture. Other definitions of culture have guided research in science communication (for example, Banks, 1988; Bullivant, 1981; Ingle and Turner, 1981; Jordan, 1985; Maddock, 1981; Samovar, Porter and Jain, 1981; and Tharp, 1989). From these works one can establish the following list of attributes of culture: communication (psycho- and socio-linguistic), social structures (authority, participant interactions), customs, attitudes, values, beliefs, worldview, skills (psychomotor and cognitive), behaviour, and technologies (artefacts and know-how). In various studies, different attributes of culture have been selected as a focus on a particular interest in multicultural communication. The definition of Phelan *et al.* (1991) of culture (above) is advantageous because it has relatively few categories and they can be interpreted broadly to encompass all anthropological aspects of culture and subculture.

Just as there are paradigms (subcultures) within the culture of science, there are subgroups in everyday life, most commonly identified by race, language, and ethnicity, but which can also be defined by gender, social class, occupation and religion. Consequently, an individual simultaneously belongs to several subgroups; for instance, an oriental female Muslim physicist or a male middle-class Euro-American journalist. Large numbers and many combinations of subgroups exist due to the associations that naturally form among people in society. Each identifiable subgroup is comprised of people who generally embrace a defining set of norms, values, beliefs, expectations, and conventional actions. In short, each subgroup shares a culture, often called a 'subculture' to convey an identity with a subgroup. One can talk about, for example, the subculture of females, the subculture of the middle class, the subculture of the television media, or the subculture of a particular science museum.

2.2. Border Crossing

An everyday scenario will illustrate the difficulties people can encounter whenever they move between cultures or between subcultures:

> George and Gracie Smith flew from North America to Spain, physically crossing political borders, but not crossing cultural borders. After waiting 45 minutes in a restaurant for their dinner bill to arrive, George finally became vocally irate over the waiter's lack of service. The waiter, in turn, became hurtfully perplexed over the fact that his impeccable manners were not appreciated.

Misunderstandings can arise whenever one of the players does not recognise a cultural border that needs to be crossed for effective communication (Aikenhead, 1996).

People often cross cultural borders so easily that they do not realise they are even there - for example, when people move between the subculture of their friends and the subculture of their family home. But for people whose peer culture is vastly different from their home culture, transitions between friends and home can be psychologically hazardous and these transitions need to be negotiated carefully. Similarly problematic are the border crossings between humanist and scientific subcultures of Western society. This problem was identified by C.P. Snow (1964) in his classic *The Two Cultures*, pointing out the inability of people to speak to one another between these two cultures.

For people who feel at ease in both a humanist and scientific culture, however, border crossing is no problem. Border crossing for them is smooth. When people feel at ease like this, cultural borders seem invisible or nonexistent. It is when people begin to feel a degree of psychological discomfort with another subculture that border crossing becomes less smooth, and needs to be managed. Contributing to their discomfort may be some sense of disquiet with cultural differences or their unwillingness to engage in risk-taking social behaviour (depending on the situation, of course). When the self-esteem of people is in jeopardy (for instance, when playing badminton with players much better than they are or when participating in an unusual social occasion such as wearing a Halloween costume), border crossing could easily be hazardous. People may react in various ways to protect their egos. Even worse, if psychological pain is involved, avoidance is the natural response and border crossing becomes impossible. These descriptors of the ease of border crossing - smooth, manageable, hazardous, and impossible - are categories that Phelan *et al.* (1991) derived from their anthropological study of high school students who had to cross cultural borders between their homes and their school. This category system was helpful to Costa (1995) in her study of students' feelings of ease in science classes. The category system will be helpful in this chapter for understanding the role of a science communicator.

Border crossing into the culture of science can be made smoother for the public if science communicators know the culture of the everyday world of the public, and can contrast that culture with a critical analysis of the culture of science (its norms, values, beliefs, expectations, and conventional actions). But even more, a science communicator must consciously move back and forth between the public's everyday world and the scientists' world - switching norms explicitly, switching values explicitly, switching conceptualisations explicitly, switching expectations explicitly, and switching language conventions explicitly. The role of a science communicator is described in more detail later in this chapter.

2.3. Values and Norms

One principal component of any culture is its values and norms. Values and norms guide scientists whenever they decide between, for example, competing theories or competing experimental methodologies (Chubin, 1981). Values and norms are learned by the apprentice scientist and they become important aspects to his or her paradigm (Hawkins and Pea, 1987; Kuhn, 1970). Longino (1990) refers to this set of discipline-centred values as constitutive values (for example, parsimony, accuracy, open-mindedness, objectivity, etc.) In contrast to constitutive values, she points to the social context outside of science in which scientists live daily. She refers to these cultural values as contextual values. Her research documented cases in which these contextual values (rather than constitutive values) influenced the decisions taken by scientists over what 'facts' to believe. She concluded that science-as-practised (as opposed to science-as-imagined) is not value-neutral. The value-neutrality of science has also been falsified by other studies (Casper, 1980; Graham, 1981; Snow, 1987; Ziman, 1984). Those who believe in the neutrality of science contend that science is free of contextual values, not constitutive values.

Therefore, science communicators must be aware of the values and norms that are potentially inherent in the language conventions of scientists (their discursive practices). For instance, one constitutive value, scientific objectivity, is often communicated to the public through science textbooks. Textbooks, however, camouflage more subtle contextual values, for example, the value 'technoscience fix' (Carlsen et al., 1994; Factor and Kooser, 1981) - the idea that solutions to societal problems (such as water contamination) only require more scientific knowledge and more innovative technologies.

Moreover, when one examines the constitutive values within science, one discovers differences between the constitutive values espoused by scientists, and the constitutive values actually practised by scientists (Mitroff, 1974). For instance, scientists publicly revere objectivity but many rely on subjective hunches in the privacy of their labs. Holton (1978) explained this apparent conflict in values by distinguishing between two types of scientific activity - 'private science' and 'public science'. Each has a different social setting and therefore a different communication audience. Public science is communicated in journals, conference proceedings, textbooks and news releases, while private science is done in labs and communicated in personal notebooks, letters, e-mails, and informal conversations.

J. TURNEY

3. MORE THAN STORY-TELLING–REFLECTING ON POPULAR SCIENCE

> Read them [popular science books] closely to appreciate how the authors sustain interest, how they impose order on seemingly disparate facts and events, how they communicate ideas and information without being pedantic, how they inform by telling stories.
>
> Wilford, 1998, p.50

1. THE NATURE OF THE BEAST

Contemplating the contribution of popular science books to contemporary science communication is both exciting and daunting. Exciting because if you happen to like your science packaged in that good old-fashioned commodity the printed book there are more science titles in the bookstores now than ever before. Daunting for the same reason, and for a couple of others too.

One is that this profusion of titles in the basic publishers' category 'popular science' is rather diverse. There is no single, easily defined genre here, rather an area in which many styles and formats co-exist (Jurdant, 1993, Turney, 1999). A more serious difficulty, though, is that it is not obvious where to look for ideas about how to evaluate this growing body of literary work. In 1962 the critic Martin Green declared that 'There is no serious or stringent idea available of what makes a book a worthy example of popularization' (Green, 1964, p.34). Although there are worthwhile critical essays on a number of individual authors (McRae, 1993), it is still true that we lack an effective critical vocabulary for discussing popular science books.

That vocabulary, I think, will have to be quite extensive, and even if I were in a position to do so there would not be space here to develop it in full. But this chapter will offer some hints about the kind of critical work we might expect it to do. As I elaborate them, I have three guidelines in mind. My comments should relate to the particular characteristics of books about science for non-professionals which may set them apart from other non-fiction. They should, if possible, make use of the academic literature in science studies or science communication. And they should offer some grounding for advice to those who wish to write such books, as well as a basis for analysing aspects of those already published.

I will mention three such aspects briefly, then go on to discuss two of them in more detail. The first is the kind of story-telling which goes on in these books. Every successful non-fiction writer will tell you that the way to engage the general reader is to tell a story. Many of these stories are pretty much like stories about anything else - they involve struggles, conflicts or adventures, have heroes and villains, complication and resolution.

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There is at least one kind of story, though, which is largely confined to the pages of science books–the story of the universe. The historical sciences are obliged to create accounts of change through time. This is perhaps better termed a narrative rather than a story, but it does give these sciences an obvious framework for popular authors to adopt. The fact that the narrative has recently been both extended and filled in with more detail makes the framework even more attractive. One important influence on science as story in the latter half of this century–along with the extraordinary vistas opened up by modern astronomical observation–has thus been the rise of cosmology as a scientific specialty. As Timothy Ferris observes, 'From the perspective of cosmic history, all scientific questions turn ultimately into narratives'. (Ferris, 1997, p.21).

This puts cosmology alongside the other sciences whose business it is to reconstruct a timeline: geology, evolutionary biology and paleoanthropology. One could add developmental biology for completeness' sake. All of these are inevitably in the business of narrative, and the details of the narrative are influenced by theoretical commitments of scientific authors, as Misia Landau, for example, has documented thoroughly for stories of human evolution (Landau, 1991).

It is also easy to observe that a large proportion of recent popular science texts draw on the work of these sciences, often recasting the technical narratives relatively lightly. Martin Eger has characterised this ensemble of texts as a new and important sub-genre of popular science, which collectively relate what he dubs the 'new epic of science' (Eger, 1993). However, while the existence of this evolutionary epic is important for understanding the appeal of many popular science books (Turney, 2001), there is more to popular science than this. And there is more to the art of writing popular science than story-telling. Furthermore, it is difficult to offer general advice about this aspect of the work, as the stories which can be told are heavily constrained by the details of the area of science and by the situation and knowledge of the author.

A second consideration which applies to the area as a whole, and is more specific to popular science, is the treatment of the nature of science. This is of interest for a number of reasons. Every narrative which relates something of what science has found, and how it was found, takes a view on the status of scientific knowledge, sometimes implicit, often explicit. Some understanding of the nature of science is also a component of most definitions of that elusive qualification for modern citizenship, scientific literacy. Finally, it is of interest because you do not have to delve very deep into the mass of popular science books to find that ideas about the nature of science are hotly contested.

This suggests that one aspect of our critical evaluation of any popular science book will be related to the way it treats the nature of science. Aside from whether we happen to agree with the particular version of the nature of science on offer, we will want to know if it is clear what the author wants to convey about this matter, and whether he or she is coherent or consistent about it. By the same token, would-be authors would do well to consider which views are in play in current popular discussion, and to reflect on where their own fit in. All of these reasons add up to a good case for making the nature of science the first topic to get closer attention below.

The second topic is explanation. If there is one thing you have to do as a science writer, it is to explain unfamiliar ideas and phenomena. But it is hard to find any systematic account of how this is done. Advice to authors usually boils down to avoiding equations, minimising jargon, striving for clarity, and using apt metaphors and analogies. It is certainly worth bearing all these in mind. Yet even when you do, it is still hard to define when the job has been done well for the intended audience.

The first of our topics obviously relates directly to academic science studies, just as the popular arguments about the nature of science are a variation on controversies about scientific knowledge which are alive in the academy. For the second, I shall turn to an area of research which science communicators are sometimes prone to ignore, on science teaching. We shall explore whether one set of terms for describing the explanatory performances of a teacher in a science classroom can be applied to the accounts science authors render of similar topics in print.

2. TRUTH, GAME, OR TRUTH GAME: VARIETIES OF SCIENTIFIC METHOD

To get a first perspective on the nature of science, consider the opening of a philosophical work which makes a historical point.

> Once, in those dear dead days, almost, but not quite beyond recall, there was a view of science that commanded widespread popular and academic assent. That view deserves a name. I shall call it Legend.
> Legend celebrated science. Depicting the sciences as directed at noble goals, it maintained that those goals have been ever more successfully realized. For explanations of the successes, we need look no further than the exemplary intellectual and moral qualities of the heroes of Legend, the great contributors of the great advances. Legend celebrated scientists, as well as science (Kitcher, 1993).

Philip Kitcher's point, of course, is that the legendary view is now widely disbelieved; that, in the thirty-odd years between the first edition of Kuhn's *Structure of Scientific Revolutions* and his own book, much historical, sociological and philosophical scholarship has called into question the picture of scientists as a band of heroes who, by their command of Scientific Method, wrest truth from Nature's grasp.

Kitcher's own intent is to evaluate the sources of this scepticism and, while acknowledging its force, nevertheless defend a version of the growth of science which provides for rational discussion of scientific progress. I am not going to comment on how well he succeeds. There are much more systematic evaluations of this widely available (Ziman, 2000). I simply want to use him to underline that what once seemed rather straightforward is now contested. In scholarly discussion, the legend is dead - what is at issue is what account of science to put in its place.

Kitcher suggests that the critique worth taking seriously is not that of what he calls 'science bashers' but of those who maintain that Legend offered 'an unreal account of a worthy enterprise'. He also maintains that Legend may still be found in 'textbooks and journalistic expositions'. But thirty years is long enough for news this important to filter out of the academy into the popular realm. And in recent popular science, too, assumptions about the nature of science have become contested terrain

One could take this up by looking at contemporary examples but consider instead someone who has been dead for 100 years, Louis Pasteur. This has the advantage that there is no dispute about the status of the science. But, as we shall see, there is ample scope for disagreement about how Pasteur's claims were established.

For instance, biochemist Frank Ashall in his enthusiastically titled *Remarkable Discoveries!* tells the story of Pasteur's work refuting spontaneous generation, and concludes that;

> Throughout Pasteur's life he encountered opposition to his theories, but he always triumphed over his antagonists. The main reasons for his success are probably his perseverance, conviction of the correctness of his ideas, the brilliance and simplicity of his experiments and the care with which they were performed. In the end, the results of his experiments were self-evident and nobody could argue with them, and they usually turned out to be correct. (Ashall, 1994, p.150)

Just the previous year, though, a pair of sociologists of science published a popular volume with the same publisher, Cambridge University Press, which relates the same episode, but comes to a very different conclusion:

> Pasteur was a great scientist but what he did bore little resemblance to the ideal set out in modern texts of scientific method. It is hard to see how he would have brought about the changes in our ideas of the nature of germs if he had been constrained by the sterile model of behaviour which counts, for many, as the model of scientific method. (Collins and Pinch, 1993, p.9)

Not long after those two books appeared, science historian Gerald Geison published a new full-scale biography of Pasteur. This was generally well-received by the reviewers, with the notable exception of the Nobel prize-winning molecular biologist Max Perutz, who wrote an extended attack on Geison in the *New York Review of Books*. Perutz's intentions were admirably clear:

> Pasteur led a simple family life and devoted all his time to research. To generations of Frenchmen, and to many others, Pasteur has been the image of the selfless seeker after the truth who has been intent on applying his science for the benefit of mankind. In *The Private Science of Louis Pasteur*, Gerald L. Geison, a historian of science, claims to have deconstructed Pasteur, and to have produced 'a fuller, deeper and quite different version of the currently dominant image of the great scientist'. I propose to deconstruct his deconstruction and restore the rightly dominant image. (Perutz, 1995)

He interprets Geison's painstaking historical treatment, drawing on new material from Pasteur's laboratory notebooks, as a salvo in the culture wars, the work of an arch-relativist out to do down a great scientific hero. So according to Perutz, Geison 'insinuates' that Pasteur cheated, 'implies that Pasteur acted dishonestly' and makes the 'accusation' that Pasteur was unethical. He denies that Pasteur could have been guilty of securing a verdict over his opponents in the spontaneous generation controversy at least partly by rhetorical means (Geison's interpretation) because, for Perutz, 'good research needs no rhetoric, only clarity'.

One could follow these arguments through, in Geison's reply to Perutz, or by looking at numerous other popular and scholarly accounts of Pasteur's life and work, but the basic polarity is clear. It is that between realism and constructivism, between seeing scientific knowledge as a true account of an underlying reality, justified by appeal to unequivocal facts, and regarding it as socially, culturally or linguistically constructed, with a much more problematic relation to the real phenomena.

If we want to explore this further, it is important to stress that, as well as being about much more than the image of Pasteur, the range of views about the nature of science is much more complex than this simple opposition suggests. We need to reduce that complexity to organise a discussion of popular science, but not quite as far as this. A useful simple inventory is offered in a British educational researchers' study of young people's images of science. (Driver, Leach, Miller and Scott, 1996). They also needed a way of classifying views of the nature of science, to help interpret students' discussions rather than popular texts, but their list will serve as a starting point.

In reviewing perspectives on the nature of science, they list five main widespread views:

> An *inductive* view of science, in which observations are paramount;
> A *Popperian* view, in which researchers try and falsify conjectures;
> A *Kuhnian* view, in which normal science is punctuated by revolutionary changes of paradigm;
> A *social constructivist* view, in which knowledge is seen as a creation of the relevant scientific community;
> An *instrumentalist* view, in which what 'works' is the principal test of which theories are accepted.

Just as their study applied these illuminatingly to the way school students think about scientific knowledge, I suggest they can help us interpret the epistemological assumptions of popular science texts. Let us try this out on a few examples.

Quantum physics is an area of science which inevitably raises questions about relations between observer and observed, causality and determinism, so books on the subject are likely to treat questions about the nature of the knowledge being described in some detail. Heinz Pagels' *The Cosmic Code - Quantum Physics as the Language of Nature* is a good example. The book was a relatively early contribution to the spate of 1980s volumes about the new particle physics. As the subtitle indicates, it takes an explicit position on the status of quantum mechanics. And it is an elaborate and subtle one. In the foreword, Pagels tells us that 'finally, there is a short third part, *The Cosmic Code*, which describes the nature of physical laws and how physicists find them' (p.12).

Turning to that section, we find a fairly lengthy discussion of the nature of science, which tells us that:

> Looking for natural laws is a creative game physicists play with nature. The obstacles in the game are the limitations of experimental technique and our ignorance, and the goal is finding the physical laws, the internal logic that governs the entire universe. (p. 299)

L.J. PRELLI

4. TOPICAL PERSPECTIVE AND THE RHETORICAL GROUNDS OF PRACTICAL REASON IN ARGUMENTS ABOUT SCIENCE

1. INTRODUCTION

Only four decades ago, scholars across the disciplines assumed that science is unique among human activities in its rigorous conformity both to empirical criteria for evidential appraisal and to formal rules for testing logical inference. Science, at its best, sought answers to questions of inquiry with recourse to foundations which, purportedly, are impervious to the inquirer's own interests, values, and preferences. Accordingly, the discourses of science, with such firm foundations in nature and in logic, are the best vehicle for bringing forward claims to knowledge that approximated, as far as humanly possible, that which is true.

Today, scholars are more apt to assume that science is constructed within a dynamic complex of social processes permeated with human interests, values, and preferences. The actual practices of scientists consist of myriad layers of decision making and judgment down to its logical and empirical core. The discourses of science, then, are not privileged since they adduce claims to knowledge that lack the special legitimacy once afforded through appeal to purportedly indisputable foundations. Those claims, it turns out, are interested, value-laden, and opinionated, as are those adduced in less epistemologically exalted fields of human endeavor.

Scientific discourse brings forward claims that are far more contingent than heretofore believed and, thus, are open to deliberation, debate, and disagreement. The presence of contingency invites *rhetorical* studies. There is a growing literature on rhetorical dimensions of science that looks to expose the play of contingency behind claims to foundational truths and certainties. In a comprehensive review of that field, Campbell and Benson (1996, p.75) saw consensus in 'the recognition that scientific perception is not immaculate; that scientific method is diverse, social, argumentative, and suasory'. They contend further that 'radical' and 'moderate' projects within the field diverge over what one commentator (Pera and Shea, 1991, p.viii) described as the belief 'that science [does] not provide genuine knowledge and that its methods and its results [are] mere social conventions' (p.75).

Those who adhere to foundationalist positions and those who oppose them still share in common the assumption that 'knowledge' rests on indisputable foundations. Foundationalists assert that point, as they stand against what they perceive as the reduction of knowledge to epistemologically groundless power struggles. Many who hold anti-foundationalist stances also assume that knowledge rests on indisputable foundations, but they instead contend that there are no such foundations

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in science and question the legitimacy of science's claim to special knowledge status.

There is a third position that does not assume that knowledge requires indisputable standards but instead redirects our efforts from what Dewey (1929) once called a 'quest for certainty' and toward explorations of situated, practical reason. Dewey's concern was how to arrive at 'concrete judgments about ends and means in the regulation of practical behavior.' The range of positions that together constitute this 'third way' do not all share Dewey's pragmatism, of course, but despite important differences they together return us to concerns about practical reason[1] (see notes at end of chapter).

In this essay, I propose to show that behind scientists' formal, published discourses operates a special logic of situated, practical reason. For guidance, I extract from rhetorical theory what I have called a 'topical' perspective for examining the informal features of this practical logic of situated argument in science. I shall first give a synopsis of that perspective. I then illustrate how to use that perspective to probe the operations of practical, rhetorical reason behind Watson and Crick's famous announcement of the DNA double helix. I conclude with a discussion of implications for this practical, rhetorical understanding of the 'logic' of argumentation in science, with attention to the problem of science literacy.

2. TOPICAL PERSPECTIVE AND RHETORICAL LOGIC

A topical perspective focuses on a special kind of situated, practical reason as an alternative to foundational approaches to argumentation. Toulmin (1983, p.398) raised questions relevant to that focus when he sought to redirect our thought about argumentation from foundational emphases on rules of universal validity to practical grounds of situated judgment:

> Are these the *right* (or relevant) arguments to use when dealing with this kind of problem, in this situation? That is, are they of a kind appropriate to the substantive demands of the problem and situation?

Practical approaches to argumentation raise questions that reveal precisely what foundational approaches conceal: they involve 'particular people, in specific situations, dealing with concrete cases, with different things at stake'. It thus becomes relevant to ask '*Who* addressed this argument to *whom*, in what *forum*, and using what *examples*' (Toulmin, 1988, p. 339).

Toulmin's questions bring us squarely into contact with rhetorical considerations. Practical reasoning requires attention to the demands on argumentation before situated audiences confronted with specific problems. Thus, we must examine arguments for patterns of judgment that constrain specific instances of practical reasoning. Those patterns are relevant to particular situations, and are not universal; they are substantive, not formal; they are practical, not theoretical.

While the operations of demonstrative logic involve reasoning from within the premises of a particular theory or conceptual framework, arguments that "apply theoretical ideas to practical situations, or which seek to criticise those theories, [must] look outside the theories and so become 'practical' or 'rhetorical' arguments" (Toulmin, 1988, p. 348). Toulmin's point can be generalised to any contested or contestible frame of reference, orientation, or conceptual viewpoint. Indeed, we could extend that point to the reportage of data, which also must evoke the right patterns of situated, audience judgment to warrant their acceptance. Put otherwise, even 'facts' never speak completely for themselves. 'External' rhetorical resources are always required.

Toulmin (1988, p. 347) directs our attention to 'trustworthy generalisations' as among the external resources that are available for adjudicating situated, practical relevance and, thus, brings us to the threshold of rhetorical theory of topical invention[2]. Here, we find some guidance on the operations and standards of situated, practical reason. I have used that theory to frame a perspective for conducting analysis of situated argumentation and judgment about science (Prelli, 1989). Conducting a topical analysis of argumentation reveals how participants (1) frame the specific points at issue, and (2) draw upon often taken-for-granted values and other thematic premises as warrants for accepting particular responses to those issues. Those values and themes, those trustworthy generalisations or *topoi* of argumentation, constrain how audiences adjudicate the situated, practical 'reasonableness' (Prelli, 1989, pp. 113-118) or 'appropriateness' (Waddell, 1990, pp. 393-395) of proffered claims[3].

Legitimating grounds that scientists share *as* scientists comprise a fairly consistent set of principles, presumptions, and premises. For instance, a fundamental principle governing scientific argumentation is that reasonable claim making involves maintaining or extending comprehension of some part of the natural world that concerns a specific community of interest. Moreover, it is widely assumed that claims advanced have emerged from prescribed methods and procedures for solving the kinds of technical problems that otherwise would have obscured that community's fuller comprehension (Prelli, 1989, pp. 120-25). Potentially reasonable arguments about science, then, advance claims that identify or modify specific problems that scientists perceive as relevant to their better comprehension of the natural order and do so through accepted procedures and methods.

Though the specific problems chosen and their formulation vary considerably, we still can make generalisations about the *kinds* of problems scientists address whenever they make and evaluate arguments about science (Prelli, 1989, pp.144-158). Scientists identify and address ambiguities or defects in evidence and data, in prevailing theories and interpretations, in received methods and procedures, and in the significance of proffered claims for the research community. Respectively, these recurrent kinds of problems or ambiguities are *evidential*, *interpretive*, *methodological*, and *evaluative*. All are 'scientific' problems, in so far as they directly or indirectly impede the efforts of a research community to maintain or extend its comprehension of natural order.

Classical rhetorical theory asserted that problems or ambiguities giving rise to debate can be framed as distinctive kinds of issues. Stripped of circumstantial details, specific issues about any problem or ambiguity are finite and reducible in structure to four fundamental kinds. *Conjectural* issues turn on whether some thing does or does not exist. *Definitional* questions turn on what constitutes the meaning of admitted things. *Qualitative* issues involve questions of how admitted and defined things apply within a particular mix of circumstances. *Translative* issues revolve around which procedures or actions are best for resolving situated problems. These four kinds of issue specify the different ways that scientists frame evidential, interpretive, methodological, and evaluative ambiguities or problems.[4]

Toulmin's 'trustworthy generalisations' resemble what were called in classical rhetorical theory *topoi* or *loci*; they are 'topics', 'regions', or 'places' where one can turn to find premises for potentially relevant lines of argument. What are the *topoi* of argumentation about science?[5] They are a veritable checklist of topics normally taken up when teaching the practical logic of scientific inquiry, if not the techniques and procedures usually glossed behind the simple rubric, 'scientific methods.' An inventory includes empirical accuracy, precision, and consistency with received knowledge. *Topoi* specially associated with theoretical claims include explanatory power, predictive power, scope or generalisability. Those and other themes and values are generally available and potentially relevant resources for argumentation that scientists can use to legitimate their specific claims as reasonable responses to specific points at issue.[6]

This partial summary of the general rhetorical grounds of practical reason shows that argument about science is neither illogical nor nonlogical; it is grounded in communally shared and conventionally understood standards of scientific reasonableness. Of course, the operations of that topical, rhetorical logic always are specific to situation; accordingly, any inspection of that logic requires attention to the practical demands and particular circumstances that generated the arguments under examination.

In the next section I illustrate the operation of topical, rhetorical logic through inspection of the practical reasoning behind Watson and Crick's classic DNA double helix announcement.

3. RHETORICAL LOGIC AND THE DNA DOUBLE HELIX

Watson and Crick's famous DNA double helix announcement (1953) initiated one of the greatest advances in twentieth century biology, furnishing what Kuhn would have defined as an exemplary problem-solution or paradigm for that field (1970). The full context of the path to DNA's three-dimensional structure is reconstructed in careful historical works about the event (Judson, 1979; Olby, 1974).
Also available are autobiographical accounts from leading participants (Chargaff, 1978; Crick, 1988; Watson, 1968). Rhetoricians found the announcement irresistible as a test case for the claim that the discourses of science are indelibly

rhetorical (Bazerman, 1981; Fisher, 1994; Gross, 1990; Halloran, 1984; Miller, 1992; Prelli, 1989).

I contend that the significant rhetorical features of the announcement are displayed prominently through its situated adaptation of an informal, topical logic. The grounds of that logic constrain (1) how issues are framed to focus points for audience adjudication and, (2) how claims are warranted as 'reasonable' or 'appropriate' responses to those issues. The announcement works to constrain audience appraisal of its proffered claims through often implied evocation of technical values and other thematic premises that scientific communities evolved as grounds for assessing 'the scientifically reasonable' during situated, practical problem solving.[7]

Much was already known about the DNA molecule when Watson and Crick started working earnestly on the problem. Its chemical composition was known since the 1930s; it consisted of phosphate and sugar groups (with attached bases). Avery (with co-workers MacLeod and McCarthy) had intimated as early as 1944 that DNA was associated with genetic material. Hershey and Chase made that point more boldly in 1952. Watson and Crick also had data about the dimensions of the molecule from published and unpublished experimental work. The central ambiguity was how all this information could be integrated within a coherent structure for the molecule.

Crick and Watson worked to solve DNA's structure at the Cavendish Laboratory at Cambridge. They were not alone in this effort. Linus Pauling was working on the problem at the California Institute of Technology and, prior to Watson and Crick's announcement, had published (with Robert Corey) a proposed structure of his own. Maurice Wilkins and Rosalind Franklin were at work on the problem at King's College in London.

Watson and Crick's article frames the problem of DNA's structure primarily as an *interpretive* problem. They set out two major claims in the opening paragraph:

> We wish to suggest a structure for the salt of Deoxyribose Nucleic Acid (D.N.A.). This structure has novel features which are of considerable biological interest' (1953a).[8]

The first claim is developed extensively through specific description and applications of their proposed model. As the piece unfolds, we see how the model integrates structural features and dimensions meaningfully within a single configuration. We also see that they did not approach the problem as primarily evidential and, thus, as requiring exacting experimental investigation before adducing their proposed solution. Experimental data were necessary but insufficient means to persuasion in this case.[9] The second major claim turns out to be *evaluative*. Once the model is established, Watson and Crick suggest with considerable brevity precisely what makes the proposed structure 'of considerable biological interest' and, thereby, establish a claim for the theoretical solution's significance.

Watson and Crick's claim to possess an answer to the structural problem logically presupposes that no meaningful theoretical structure existed. They had to

R. ECKERSLEY

5. POSTMODERN SCIENCE: THE DECLINE OR LIBERATION OF SCIENCE?

1. INTRODUCTION

I sometimes think that the appeal of postmodernism to many people, myself included, is that it relieves us of the effort of trying to make sense of a world that no longer seems to make sense. This would have profound implications for science, which is, after all, about making sense of the world.

It is not that simple, of course. But postmodernity does pose interesting and important challenges for science – and for science communication and the public understanding of science. Science communication is, and must be, about much more than 'selling' science to the public. Fundamentally, it concerns the relationship between science and society, and it has a powerful role in shaping this relationship and also in what science is done and how it is used, not just economically, but culturally too. This means science communication is also closely associated with science policy issues.

In this chapter, I want to look broadly at several different - but, I think, related - aspects of how science could influence and be influenced by cultural developments, especially in modern Western societies. In particular, I want to look at the possible impact on science of the cultural changes associated with postmodernity, the relationship between science and material progress, and, finally, the potential for a reconciliation between scientific and spiritual world views. All have far-reaching implications for humanity. And depending on how these matters are played out, we could see, in the 21st century, either the decline or liberation of science.

2. POSTMODERNITY AND SCIENCE

Postmodernity (or late modernity, as some scholars prefer to call it) describes a world coming to terms with its limitations, including the recognition that the 'modern' dream of creating a perfect social order is ending, and that some of our problems may be insoluble. Postmodernity is marked by ambivalence, ambiguity, relativism, pluralism, fragmentation, contingency and paradox. There are no grand narratives or creeds that define who we are and what we believe, but a multiplicity of them.

Science and technology are among the key instruments of the modernist vision. As Anthony Elliott (1996) states:

> Science, bureaucracy and technological expertise serve in the modern era as an orientating framework for the cultural ordering of meaning. (pp. 18 - 19).

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This changes in a postmodern world. Elliott argues that the vision of the Enlightenment has faded.

> The grand narratives that unified and structured Western science and philosophy... no longer appear convincing or even plausible

From a postmodern perspective, he says,

> knowledge is constructed, not discovered; it is contextual, not foundational.

Elliott (1996) argues that knowledge generated by experts and institutions is no longer equated with increasing mastery and control of the social order. In fact, he says, the advance of modernisation is increasingly equated with the production of risks, hazards and insecurities on an unprecedented global scale.

> Put more accurately, technological knowledge and control of the social world today are as much about managing socially produced risks and dangers which are worldwide in their consequences as about unbounded mastery in the service of political domination. (pp. 66-70)

The profound paradox of our situation is well described by Marshall Berman (cited by Elliott, 1996), who said:

> To be modern is to find ourselves in an environment that promises us adventure, power, joy, growth, transformation of ourselves and the world - and, at the same time, that threatens to destroy everything we have, everything we know, everything we are. (p. 11)

So we can see that there are two aspects to the postmodernist critique of science: epistemic relativism; and science as a two-edged sword.

Scientists are most hostile to the first charge - that scientific knowledge is culturally adulterated. I do not entirely agree with this assertion. Scientific knowledge does transcend its cultural context; science does 'advance' in a way that is, I think, unique. But scientific knowledge is never the whole truth or an absolute, immutable truth. And what science is done, and how its results are applied, are powerfully determined by its cultural context.

So, given that we choose into which corner of the dark cavern of the unknown we shine the light of scientific inquiry, and given that we will never light up everything, then we do need to acknowledge the degree to which what we see depends on what influences our choice of where to look and what to look for - that is, on who we are and what we believe. This degree of cultural construction depends on the science: smaller in the case of the physical sciences, larger in the social; lesser in pure science than in applied.

The second charge against science - that it is a mixed blessing - is uncontestable, and doesn't need elaboration. This applies to specific products of science (technologies) such as nuclear energy, pesticides or genetic modification, or more broadly to the whole relationship between science and material progress - a subject to which I will return later.

There is a second factor which could compound the effect of postmodern thinking on science: the possibility that science may have to confront its own intrinsic limitations.

John Horgan (1996) has argued that we must accept the possibility that the great era of scientific discovery is already over. He is not referring to applied science, which still has an abundance of problems to solve, but what he calls 'science at its purest and grandest, the primordial human quest to understand the universe and our place in it'. Horgan develops an idea propounded by Gunther Stent in *The Coming of the Golden Age: A View of the End of Progress*, published thirty years ago. Stent argued that if there are any limits to science, any barriers to further progress, then science may well be moving at unprecedented speed just before it crashes into them. When science seems most muscular, triumphant, potent, that may be when it is nearest death, Stent said.

> Indeed, the dizzy rate at which progress is now proceeding makes it seem very likely that progress must come to a stop soon, perhaps in our lifetime, perhaps in a generation or two.

Horgan implies three different reasons for this view. One reason is that all the major discoveries–or should we call them 'constructions'?–may have been already made:

> Now that science has given us its Darwin, its Einstein, its Watson and Crick, the prospect arises that further research will yield no more great revelations or revolutions but only incremental, diminishing returns.

(He discusses, but dismisses, the claim that scientists thought this about physics last century.) Another reason is that even seemingly open-ended sciences like physics inevitably confront physical, financial and even cognitive limits: modern physics, for example, is becoming increasingly difficult for anyone, even physicists, to comprehend. A third factor is the intrinsically indeterministic nature of many natural phenomena - that is, they are unpredictable and apparently random–making them resistant to scientific analysis. The work emerging from chaos and complexity theories demonstrates that science, when pushed too far, culminates in incoherence.

I am not necessarily endorsing Horgan's arguments, only suggesting they deserve consideration in looking at the future of science.

3. POSTMODERN SCIENCE

So science is being assailed by two forces: the first, postmodernism and its challenge to science's social and intellectual authority; the second, science's own 'limits to growth'. What will be the consequences?

While technological innovation will continue apace, science will cease to be the defining and dominant feature of our society. It will co-exist, often uncomfortably, with irrationalism, superstition and other belief and knowledge systems. In losing its ideological dominance as the source of progress, science is losing its own internal coherence, and the philosophy and culture that have held it together. While good science will remain rigorous and empirical, this will be more a question of professional ethics and sheer pragmatism - this science delivers the best results - than the sort of ideal represented by sociologist Robert Merton's four norms of science: universalism, communism, disinterestedness and organised scepticism.

Like everything else, science is fragmenting. Much more openly and unequivocally than in the past, science today serves different masters and different purposes. Its culture and norms become those of its users. Thus, it is increasingly meaningless to talk about a single form of scientific progress, or about attitudes to science in any generic sense. Public opinion about science depends on which public and which science. The epigraph on the United States National Academy of Sciences building in Washington–

> To science, pilot of industry, conqueror of disease, multiplier of harvest, explorer of the universe, revealer of nature's laws, eternal guide to truth

will, with its implied congruence and attainability of all these goals, its unified vision of progress, become a quaint anachronism in the postmodern world.

This is already apparent from surveys of how people perceive science and technology. They are ambivalent and contradictory in their views - and also discerning. Take, for example, a study I initiated several years ago, under the auspices of the Australian Science, Technology and Engineering Council, which explored young people's hopes and fears for Australia in the year 2010: a key finding was the extent to which views on science and technology were embedded in a wider social context (Eckersley, 1999). The role young people saw for science and technology changed markedly between their expected and preferred futures.

Young people are not so much *against* science and technology. Indeed, they acknowledge their importance in achieving a preferred future. But they are astute enough to realise science and technology are tools, and their impacts depend on who controls them and whose interests they serve. They *expected* to see new technologies used further to entrench and concentrate wealth, power and privilege. They *wanted* to see new technologies used to help create closer-knit communities of people living a sustainable lifestyle.

For example, young Australians (aged 15-24) were asked in one poll question to agree or disagree with nine specific statements about science and technology. The responses showed that:

> Young people believed science and technology offered the best hope for meeting the challenges ahead (69%), but also that they were alienating and isolating people from each other and nature (53%).
>
> They believed that computers and robots were taking over jobs and increasing unemployment (58%), and a significant minority believed that they would eventually take over the world (35%).
>
> They were more likely to think that governments would use new technologies to watch and regulate people more (78%) than they were that new technologies would strengthen democracy and empower people (43%).
>
> They expected science to conquer new diseases (87%), but not that it would find ways to feed the growing world population (39%), or solve environmental problems without the need to change lifestyles (45%).

In another question, young people were asked to nominate which of two positive scenarios for Australia in 2010 came closer to the type of society they both expected and preferred:

> A fast-paced, internationally competitive society, with the emphasis on the individual, wealth generation and 'enjoying the good life'. Power has shifted to international organisations and business corporations. Technologically advanced, with the focus on economic growth and efficiency and the development of new consumer products.
>
> A 'greener', more stable society, where the emphasis is on cooperation, community and family, more equal distribution of wealth and greater economic self-sufficiency. An international outlook, but strong national and local orientation and control. Technologically advanced, with the focus on building communities living in harmony with the environment, including greater use of alternative and renewable resources.

Almost two thirds (63%) said they expected the first, 'growth' scenario. However eight in ten (81%) said they would prefer the second, 'green' scenario. About a third (35%) expected the 'green' scenario, and 16% preferred the 'growth' scenario.

One possible consequence of postmodernity is that science will become a greatly diminished cultural influence in our lives and in national affairs (even while we continue to embrace its products). For example, Horgan (1996) sees the limitations of science contributing to a growing reluctance by the public to support science, and even to the rise of anti-scientific sentiments. He notes that Oswald Spengler foresaw the disillusionment with science in *The Decline of the West*, published in 1918: Spengler predicted that the demise of science and the resurgence of irrationality would begin at the end of the millennium. As scientists became more arrogant and less tolerant of other belief systems, notably religions, he believed society would rebel against science and embrace religious fundamentalism and other irrational systems of belief.

There are signs that this might be happening, although public sentiment has not so much swung against science and technology as shifted towards superstition and fundamentalism. For example, Americans view science and technology as the engines of the past century's economic prosperity and the main reasons for the improvements in their well-being, and are optimistic about further gains in the next century. Yet they also express misgivings about the way their country has changed culturally and spiritually (Pew, 1999). Asked in a recent poll what was more important, encouraging a belief in God or encouraging a modern scientific outlook: 78% of Americans chose 'a belief in God', and only 15% 'a modern scientific outlook' (Washington Post/Kaiser/Harvard, 1998). Over a third (36%) believe the Bible is the actual word of God, to be taken literally word for word, while almost half (48%) believe it is the inspired word of God, but not everything in it should be taken literally. Only 14% regarded the Bible as an ancient book of fables, legends, history and moral precepts recorded by man.

But there are also other possibilities. In the early 1990s, I wrote in essays for the Australian Commission for the Future and *The Futurist* that science could play a crucial role in achieving the sort of cultural or values shift necessary to address 21st