5

Of deficits, deviations and dialogues

Theories of public communication of science

Massimiano Bucchi

Theoretical and empirical research in public communication of science has a relatively short history compared with the long-standing practice of communicating science to the public. It was only in 1992, for instance, that a dedicated scholarly journal, *Public Understanding of Science*, was founded. This chapter seeks to contribute to the theoretical understanding of science communication by, first, outlining the key elements of the traditional conception, still implicitly or explicitly widespread within science communication practice and policy, of public communication of science. I then review some of the studies that have challenged different facets of this conception. Finally, I raise the question of which alternative models can best help us understand the contemporary interactions between scientific knowledge and the general public.

The traditional conception of public communication of science

Scientific communication addressed to the layman has a long tradition. Consider the numerous popular science books written in the 18th century to satisfy growing public interest, especially among women, including Algarotti's *Newtonianism for Ladies* or de Lalande's *L'Astronomie des Dames*, the numerous accounts of scientific discoveries published in the daily press, or the great exhibitions and fairs that showed visitors the latest marvels of science and technology (Raichvarg and Jacques 1991).

However, communication practices in science have developed mainly in relation to two broad processes: the institutionalisation of research as a profession with higher social status and increasing specialisation; and the growth and spread of the mass media.

The idea that science is 'too complicated' for the general public to understand became established particularly as a result of advances made in physics during the early decades of the 1900s. In December 1919, when observations made by astronomers during a solar eclipse confirmed Einstein's general theory of relativity, the *New York Times* gave much prominence to a remark attributed to Einstein himself: 'At most, only a dozen people in the world can understand my theory' (cited by Pais 1982: 309).

This idea underpins a widespread conception, if not an outright 'ideology', of the public communication of science. Other cornerstones of the conception are the need for mediation between scientists and the general public, made necessary by the complexity of scientific notions; the singling out of a category of professionals and institutions to perform this mediation (science journalists and, more generally, popularisers of science, museums and science centres); and use of the metaphor of translation to describe this mediation.

This 'diffusionist' conception, unquestionably simplistic and idealised, which holds that scientific facts need only be transported from a specialist context to a popular one, is rooted in the professional ideologies of two of the categories of actors involved. It legitimates the social and professional role of the 'mediators' – popularisers, particularly science journalists – who comprise the most visible and most closely studied component of the mediation. It also authorises scientists to proclaim themselves extraneous to the process of public communication so that they may be free to criticise errors and excesses – especially in terms of distortion and sensationalism. There has thus arisen a view of the media as a 'dirty mirror' held up to science, an opaque lens unable adequately to reflect and filter scientific facts.

In addition, this vision has emphasised the public's inability to understand and appreciate the achievements of science due to prejudicial public hostility as well as to misrepresentation by the mass media, and adopts a linear, pedagogical and paternalistic view of communication to argue that the quantity and quality of the public communication of science should be improved. In order to recover this deficit, public and private bodies – especially since the mid-1980s – have launched schemes aimed at promoting public interest in and awareness of science. These initiatives have included 'open days', now a routine feature of many laboratories and research institutions, science festivals and training courses in science journalism.

In summary, the traditional, diffusionist conception of public communication of science incorporates a notion of:

1. the media as a channel designed to convey scientific notions, but often unable to perform this task satisfactorily due to lack of competences and/or predominance of other priorities (e.g. commercial interests);
2. the public as passive, whose default ignorance and hostility to science can be counteracted by appropriate injection of science communication;
3. science communication as a linear, one-way process in which the source context (specialist elaboration) and target context (popular discourse) can be sharply separated, only the former influencing the latter;
4. communication as a broader process concerned with the transfer of knowledge from one subject or group of subjects to another;
5. knowledge as being transferable without significant alterations from one context to another, so that it is possible to take an idea or result from the scientific community and bring it to the general public.

Although such notions have mutually reinforced each other, and have sometimes overlapped to some extent, it could be noted that one of the labels most frequently used to refer to this whole constellation of notions, the 'deficit' model, refers in particular to the second assumption above. Regarding the first assumption, within the past three decades research on media coverage of science issues has gone beyond the mere stereotype of the diffusionist conception and its pleas for greater accuracy, for closer interaction between journalists and specialist sources, and, in general, for efforts to minimise the elements that cause 'disturbance' in communication between scientists and the general public, which otherwise would be straightforward. In this light, for instance, the role of newsmaking routines and journalistic priorities in shaping science coverage has been articulated (see Chapter 2 in this volume). Likewise, the media's criteria for selecting 'scientific experts' to comment on a specific issue do not necessarily coincide with those of the scientific community. Journalists – particularly news journalists as opposed to 'specialised' science journalists – have also sometimes reacted forcefully to the expectation that their criteria should correspond to those of scientists, seeing it as their professional duty to express public concerns and demands, and describing their mission in terms of public opinion's need for information, thus justifying their indifference to the priorities of the scientific agenda (Hansen 1992; Peters 1995).

However, long-period analysis of the treatment of scientific themes by the non-specialist press shows that it presents scientific activity as largely 'progressive', as beneficial to society, and as consensual. Such coverage is found to adhere closely to specialist sources, often cited directly or indirectly, and in linguistic terms is often not particularly distant from specialist communication.[1]

Is the public scientifically illiterate?

The diffusionist (pedagogical–paternalistic) conception of the communication of science has long informed studies on public scientific knowledge. First conducted in the USA during the 1950s, research on the general public's interest in and awareness of science and scientific information has, since the 1980s, become common in numerous countries. The results of this research have frequently been used to decry the public's scant interest in science and its excessively low level of 'scientific literacy', and to call for quantitative and qualitative improvements in science communication addressed to the public at large. Since the early 1990s, these assumptions have been strongly criticised on several grounds. It has been pointed out that the equation between public understanding and the ability to answer questions about science has long restricted the discussion to the somewhat tautological observation that members of the public do not reason in the same way as professional scientists. Also disputed are the assumed links between exposure to science in the media, level of knowledge, and a favourable attitude toward research and its applications. As regards biotechnologies, for example, recent research has shown a substantial degree of scepticism and suspicion, even among the sections of the population most exposed to scientific communication and best informed about biotechnological topics (Bucchi and Neresini 2002). In general, it does not seem that the opposition of certain sectors of the general public to particular technical–scientific innovations is due solely to the presence of an information deficit. Rather, the phenomenon requires more systematic and detailed analysis.

More generally, the disjunction between expert and lay knowledge cannot be reduced to a mere information gap between experts and the general public as envisaged by the deficit model. Lay knowledge is not an impoverished or quantitatively inferior version of expert knowledge; it is qualitatively different. Factual information is only one ingredient of lay knowledge, in which it interweaves with other elements (value judgements, trust in the scientific institutions, the person's perception of his or her ability to put scientific knowledge to practical use) to form a corpus no less sophisticated than specialist expertise (Wynne 1989, 1995).

The role of scientists

And what about scientists? Are they truly extraneous to these processes, passively at the mercy of the discursive practices of journalists and the incomprehension of the public? Studies on the public communication of science tell us that they are not: around 80 per cent of French researchers report that they have had some experience of popularising science through the mass media, and similar conclusions were reached in a study on US scientists by Dunwoody and Scott (1982). Almost one-fifth of the articles on science and medicine published in the past 50 years by the Italian daily newspaper *Corriere della Sera* have been written by science/medical experts (Bucchi and Mazzolini 2003). According to a broad survey of British scientists and journalists, already in the early 1990s more than 25 per cent of the articles on science that appeared in the press started from initiatives – press releases, announcements of discoveries, interviews – by researchers and their institutions, a percentage that is likely to have increased since then (Hansen 1992). Researchers are often among the most assiduous users of science coverage by the media, on which they draw to select from the enormous mass of publications and research studies in circulation. A paper published in the prestigious *New England Journal of Medicine* is three times more likely to be cited in the scientific literature if it has first been mentioned by the *New York Times* (Phillips 1991). The visibility of scientists in the media tends to display a pyramid structure very similar to that of the distribution of other resources and remunerations in the scientific community. At the top of the pyramid stand a very small number of 'celebrities' who are frequently consulted on non-scientific issues as well – Nobel prize-winners being a typical example – and below them, a broad base with very sporadic visibility (Goodell 1977). These results have also prompted sociologists of science to interest themselves in the public communication of science, a topic on which their contribution has long been marginal in comparison with other disciplines including social psychology, linguistics and media studies. This lack of interest in the public presentation and awareness of science can be explained by considering sociologists of science to be the most sophisticated victims of the traditional conception. As long as the public communication of science was considered a practice detached from science, it was of scant relevance to those interested in the influence of social factors on scientific activity.

Public communication of science as the continuation of scientific debate by other means

Science studies are highly critical of the traditional conception of the public communication of science. Instead of the sharp distinction between science and its popularisation, they propose a 'continuity' model of scientific communication (Cloître and Shinn 1985; Hilgartner 1990). Along the continuum thus envisaged, gradual differences can be discerned in the diverse contexts and styles of communication/reception that exist in the exposition of scientific ideas. Cloître and Shinn (1985) identify the following four main stages in the process of scientific communication.

- *Intraspecialist level* – the most distinctively esoteric level, typified by papers published in specialised scientific journals. Empirical data, references to experimental work and graphs predominate.
- *Interspecialist level* – includes various kinds of texts, from interdisciplinary articles published in 'bridge journals' such as *Nature* and *Science* to papers given at meetings of researchers belonging to the same discipline, but working in different areas.
- *Pedagogic level* – described by Fleck (1935) as 'textbook science', where the theoretical corpus is already developed and consolidated and the current paradigm is presented as complete. The emphasis is on the historical perspective and the cumulative nature of the scientific endeavour.
- *Popular level* – covers for instance articles on science published in the daily press and the 'amateur science' of television documentaries. Cloître and Shinn point to the quantity of metaphorical images in these texts and their marked attention to issues concerning health, technology and the economy.

A typology of this kind, which presents science communication as a continuity of texts with differences in degree, not in kind, across levels, invites us to imagine a sort of trajectory for scientific ideas that leads from the intraspecialist expository context to the popular one, passing through the intermediate levels. This is a trajectory congruent with theories, from Fleck's to Latour's, on the construction of scientific facts. We may take as an example the tortuous process studied by Fleck, which led from a vague popular idea of 'syphilitic blood' to introduction of the Wassermann reaction and definition of the clinical distinctiveness of syphilis. This highly provisional definition, hedged about by doubts and methodological caveats, rapidly became an incontrovertible certainty in the eyes of the general public. Fleck used this example to reflect on the path followed by a medical–scientific notion from what he called the esoteric circle (the specialist community) to the exoteric one (the general public). Fleck compared a report on a clinical examination drawn up by one specialist for another with a report prepared for a general practitioner, which 'does not represent the knowledge of the expert. It is vivid, simplified and apodictic' (Fleck 1935, Eng. tr. 1979: 113).

Specialist exposition – the 'science of the journals' – is provisional and tentative. But when a theory makes its entry into the textbooks, it partly loses these features and is presented to the reader as generally accepted by the medical–scientific community:

in other words, it becomes a 'fact'. A further step comes with the exposition characteristic of popular science; here 'the fact becomes incarnated as an immediately perceptible object of reality' (ibid. 125). At the popular level, doubts and disclaimers disappear: the distinctions and nuances of specialist knowledge condense into elementary and compact formulas: AIDS is HIV; psychoanalysis studies 'complexes'; the neurological theory that hypothesises a division of tasks between the two hemispheres of the brain is transformed into a sharp antithesis between 'right-dominated' and 'left-dominated' people. The communicative path from specialist to popular science can thus be illustrated as like a funnel that removes subtleties and shades of meaning from the knowledge that passes through it, reducing it to simple facts attributed with certainty and incontrovertibility (Figure 5.1). Fleck stresses that this progressive solidification of knowledge then exerts an influence on specialists themselves. 'Certainty, simplicity, vividness originate in popular knowledge. That is where the expert obtains his faith in this triad as the ideal of knowledge. Owing to simplification, vividness and absolute certainty [popular knowledge] appears secure, more rounded and more firmly joined together' (ibid. 113, 115). The passage of a scientific notion through these various levels therefore cannot be described as the simple translation of an object from one communicative context to another. Each step – and this is one of the central messages of Fleck's book – involves a change in the notion. By way of analogy, something similar happens to characters and stories in literature. For example, none of Arthur Conan Doyle's original works contains the expression 'Elementary, my dear Watson'. Only after its introduction in a theatre production of the detective's adventures did the phrase come to epitomise Sherlock Holmes in the popular imagination.

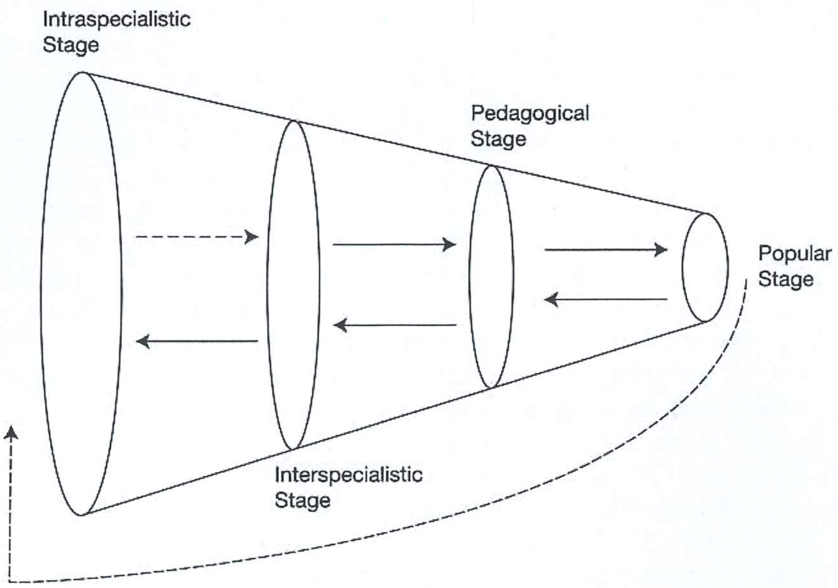

Figure 5.1 A model of science communication as a continuum.
Source: Bucchi 1998

Taking this intuition to its extreme, studies by sociologists of science based on the continuity model consider the level of popular communication to be the final (and often decisive) stage in the process of stylisation, 'distancing from the research front', and production of factuality and incontrovertible truth that constructs scientific evidence (Collins 1987). As Whitley (1985: 13) puts it, 'The more removed the context of research is from the context of reception in terms of language, intellectual prestige and skill levels, the easier it is to present their work as certain, decontextualised from the conditions of its production, and authoritative.'

The continuity model can be considered a useful frame of reference insofar as it describes some sort of ideal flow of communication in routine circumstances. However, in some cases, public communication seems able to perform a more sophisticated role, for example in bringing a scientific matter to attention of policy-makers and, consequently, of the wider scientific community, as happened in the case of sickle-cell anaemia in the USA (Balmer 1990).

In this case we can speak of a 'deviation' to the public level, because the discourse did not follow the usual trajectory, but passed directly at the public level to then influence specialist circles. The importance of appealing to the public in particular cases of change of controversy or paradigm has been variously hypothesised and studied (Jacobi 1987). For example, the wide and enthusiastic coverage given in 1919 by the daily press to the solar eclipse observations as confirming Einstein's theory of relativity – *The Times*' headline was 'Revolution in Science: New Theory of the Universe: Newtonian Ideas Overthrown' – played a crucial role in publicly settling an issue that was still being debated within specialist circles (Gregory and Miller 1998).

Mention has already been made of how scientists make use of the information and images that circulate at the public level. Cloître and Shinn (1985) document how specialists appropriated a metaphor (the ant in the labyrinth) originally used by popular science texts to explain the Brownian motion of particles. Around one-third of the scholars involved in the debate on the connection between mass extinction of dinosaurs and a meteor collision with the Earth – another controversy with broad public resonance – stated that they had heard of the impact hypothesis from the mass media (Clemens 1994).

It has been argued that scientific discourse at the public level may, in some cases, resemble certain forms of political discourse in that it is only apparently public. It is not really addressed to the public, but instead is intended to reach a large number of colleagues rapidly. To do so, it uses the public level as a shared arena where it is not necessary to comply with the constraints of specialist communication. This prerogative of the public level is particularly important when communication must pass through several disciplinary sectors (a case in point being the hypothesis on the extinction of the dinosaurs, which concerned palaeontologists, geologists and statisticians) or several categories of actors. In the late 19th century, Pasteur's struggle to legitimise the anthrax vaccine and, more generally, the idea that diseases could be prevented by appropriate inoculation with the infectious agent, meant that physiologists, doctors, veterinarians and farmers had to be addressed simultaneously. This difficult task was achieved by means of a public experiment organised in 1881 on a farm, where vaccinated and non-vaccinated cattle were infected with anthrax before the eyes of hundreds of people, including French and foreign newspaper reporters, who wrote numerous detailed articles on Pasteur's success. Communication at the public level enabled the French physiologist to play down still unclear theoretical issues by emphasising practical ones (of great importance to some groups in his audience, e.g. farmers and politicians) such as the effectiveness and cheapness of his method. Moreover, immunisation and the related practice of inoculation had long been familiar to the lay peasant culture (Bucchi 1997).

In 1919, Einstein was able simultaneously to address different disciplinary audiences (physicists, astronomers, mathematicians) through the popular press by giving interviews and writing articles on his theory of relativity (Gregory and Miller 1998). The scientists who argued that the depletion of the ozone layer was due to CFC found the widely publicised image of the ozone 'hole' to be an effective device through which to alert researchers, politicians, environmentalists and public opinion to the emergency. The rapid public consensus achieved with the Montreal Protocol of 1987, which provided for international agreements to reduce the CFC emissions responsible for ozone depletion, indirectly reinforced the status of a body of knowledge that was still being carefully debated by specialists (Grundmann and Cavaillé 2000).

When a new sector of research is being established or consolidated – as happened with climate studies or the neurosciences in past decades – the public arena is vital if researchers are to communicate among different disciplines. Communicating in public enables scientists not only to talk – albeit indirectly – among themselves (as Fleck pointed out), but also to gain recognition and construct a shared identity in terms of research interests and methods, thereby laying the basis for institutionalisation of their sector.

In cases of 'deviation', therefore, the science communication process should be depicted as much more complex. In these situations, the public discourse of science does not receive simply what is filtered through previous levels, but may instead find itself at the centre of the dynamics of scientific production. By and large, when talking about the public communication of science, we are referring to at least two different things:

- a routine trajectory, consensual and non-problematic, which is adequately described by the continuity model – despite its ideological connotations, 'popularisation' is a sufficiently appropriate term for this process;
- an alternative trajectory, which is the one represented by deviation to the public level, so that public communication acquires even greater salience and a more articulated role compared with specialist debate.

There are major formal and substantial differences between these two trajectories. At a formal level, when the popularisation mode is activated, scientific problems are more frequently addressed in settings devoted explicitly to the communication of science: popular science magazines and the science pages of newspapers. Placing scientific notions in these media 'frames' gives them legitimacy and enhances their credibility. The most obvious example is the museum medium: the display of a scientific artefact in a museum tends automatically to confer the status of incontrovertible 'fact' upon it (Macdonald and Silverstone 1992).

When deviation occurs, scientific problems appear more frequently in generic media settings as well, such as the news sections of newspapers and television newscasts. The scientific facts, as well as the networks of professional and institutional actors surrounding them, may be consolidated, as the continuity model envisages, but they may also be dissolved, deconstructed or simply manipulated by social groups for their own purposes. The funnel does not necessarily taper off; it may expand again towards the specialist levels. In these situations, social actors outside the research community, such as activists or representatives of patients' associations may play a significant role in the definition of scientific facts, as in the case of research on AIDS (Grmek 1989; Epstein 1996).

Study of public scientific discourse in cases of deviation enables account to be taken of the 'plurality of the sites for the making and reproduction of scientific knowledge' (Cooter and Pumfrey 1994: 254), and also gives a more sophisticated role to the public, who the funnel model tends to reduce to no more than a passive source of external support. A theory or a scientific finding may consequently enjoy different status and robustness at different levels of communication. Thus the Big Bang may represent *the* explanation of the origin of the universe in the popular domain, despite the doubts and distinctions expressed in the specialist one.

While deviation may be an opportunity to evade the rules and constraints of the popularisation process, it is often regarded with suspicion by the scientific community. When scientific problems are pushed into the public arena, they lose some of the status that they may still enjoy in such popularisation frames as the scientific journals or the science sections of newspapers. They may, for example, be subject to problem concatenation processes, or undergo life cycles like all other issues of public interest. Moreover, they can presumably also be manipulated and introduced into the public arena by actors external to the scientific community, such as journalists, policy-makers or the leaders of movements and associations.

This helps explain the growing efforts by scientists to extend their control over communication with the public. Scientific institutions organise seminars on these matters and invite journalists to 'live laboratory life' for brief periods; researchers write booklets advising their colleagues on how to handle the media. Research institutes now make much use of public relations offices and similar devices, not to exclude the possibility of deviations (which would be difficult to achieve), but to extend the scientific community's control over recognition of 'crises' and over the activation of deviation processes so that the latter can be put to *ad hoc* use or criticised. Scientists often engage in deviation (public communication as part of the process by which a scientific fact is produced), but camouflage it as popularisation (the diffusion of scientific knowledge with pedagogic intent). Many of the misunderstandings that surround the debate on the public communication of science probably arise because popularisation expectations are attributed to communications that, in reality, perform deviation functions – they serve to regulate the scientific debate for 'internal' purposes – and *vice versa*.[2] There is tension within the scientific community between the institutionalisation of deviation – its absorption into ordinary expository practice (popularisation) in order to prevent its 'uncontrolled abuse' – and its defence as a sort of 'emergency exit' for certain situations, and as a potential source of scientific change and innovation.

Can knowledge be transferred?

If the public and the media have been problematised since the initial reflections on science communication – and science has been more recently problematised in the same context (see e.g. Wynne 1995; Michael 2002) – communication itself as a concept has, so far, rarely been problematised. Much of the diffusionist ideology of science communication fundamentally rests on a notion of communication as transfer. For at least 60 years such a notion has been the dominant paradigm for describing communication – for scholars, practitioners and lay persons – as a process concerned with the transfer of knowledge from one subject or group of subjects to another subject or group of subjects. The widespread and unquestioned use of keywords such as 'reception', 'flow', 'distortions' and 'target' when discussing communication is indicative of the power and pervasiveness of this transfer metaphor. Within this notion, successful communication is defined as the achieved transfer of information from one party to another; for instance, a public communication initiative in the area of genetics could be considered successful if a fraction of the knowledge available to the scientific community on this topic is acquired by a certain target public. This notion takes for granted, among other things, the possibility of transferring knowledge without significant alteration from one context to another, so that we can simply take an idea from the scientific community and bring it to the general public; and that the same knowledge in different contexts will result in the same attitudes and eventually in the same type of behaviour. Beginning in the 1950s, a great number of studies in the area of communication – and in particular, mass communication – have challenged some of the core elements of the transfer vision. Studies have shown, among other things, that different types of filter can contribute to make the transfer a selective process. Filters include selective perception of media messages, previous motivations and attitudes of audiences, and communication intermediaries such as opinion leaders.[3] In the specific domain of science communication, several empirical and theoretical contributions have critically addressed the idea of transfer during the past two decades.

A necessarily selective list of the aspects which have been pointed out includes:

- the non-linearity of the communication process; science communication need not necessarily spring from specialised contexts, but can also originate in popular, non-specialised arenas (Lewenstein 1995a, 1995b; Bucchi 1996, 1998);
- the reception of science communication is not a passive process, but a complex set of active transformative processes that can, in turn, have an impact on the core scientific debate itself (Wynne 1989, 1995; Epstein 1996);
- specialist exposition of science theories and results (the source of transfer in the traditional paradigm) cannot be sharply separated from popular exposition (the target of transfer), despite the fact that distinctions between the two forms of exposition are often used by scientific actors as a rhetorical strategy (Hilgartner 1990);
- the science communication process can be better represented as a continuous sequence of expository levels, gradually shifting one into another with differences in degree and not in kind, mutually influencing one another (Cloître and Shinn 1985; Hilgartner 1990; Lewenstein 1995a; Bucchi 1996, 1998).

There are also several indications that public discourse about many science issues has not arisen as a filtered or trickled-down version of specialist discourse. In his study of genetics in popular culture, to continue with this example, Jon Turney (1998) has shown that key achievements in terms of research agenda, including Watson and Crick's discovery of DNA structure, did not receive immediate attention by the general media; on the other hand, popular ideas on the transformation of species and modification of man had a much longer history, as documented for instance by the famous claim by French novelist Emile Zola – 30 years before the rediscovery of Mendel's laws of heredity – that 'heredity has its laws, just like gravitation' (Zola 1871; see also Lewontin 1996).

Understanding of science communication may benefit from stepping out of the transfer metaphor to investigate the multiple interactions of specialist and popular discourse. Communication may thus be seen as intense short-circuiting or cross-talking between those discourses – rather than as plain transfer – taking place under certain circumstances and centring on key discursive 'boundary objects' (e.g. gene, DNA, Big Bang, AIDS) lying at the intersection between specialist and popular levels.

Such objects make communication possible without necessarily requiring consensus, for an object may be interpreted and used in quite different ways within different types of discourses. 'Gene' could thus be seen as a boundary object, a label employed in both specialist and public contexts and thereby providing a common language, although translated in different ways in a laboratory conversation and in a car advertisement.[4] In this light, the spell intrinsically tying communication to understanding, as in the deficit vision, can finally be broken.

A model of science communication as cross-talk also implies seeing communication not simply as a cause – for instance, of changes in opinions and attitudes among the public, due to the transfer of certain results or ideas – but also as the result of developments in both discourses, allowing the formation of an intersection zone. It is reasonable to hypothesise that, once formed, this intersection would facilitate exchanges across different discourses, reinforcing itself in a recursive fashion. Another advantage could be seen in the model's recapturing a view of communication as a process – which sustains (and has to be sustained by) actors' interaction – rather than as a taken-for-granted point of departure.

From deficit to dialogue, from dialogue to participation – and beyond?

During the past decade, enduring public concern over certain science and technology issues despite significant communication efforts; growing citizen demand for involvement in such issues; and multiplying examples of non-experts actively contributing to shaping the agenda of research in fields such as biomedicine have led to a rethinking of the very meaning of public communication of science in several arenas. For instance, in 2000 a report from the UK House of Lords acknowledged the limits of science communication based on a paternalistic, top-down science–public relationship, and detected a 'new mood for dialogue'. In 2002, the Committee on the Public Understanding of Science (Copus), set up in 1985 by the

Royal Society and other institutions to support public awareness activities, was also brought to an end by its very founders, who reached the conclusion that 'the top-down approach which Copus currently exemplifies is no longer appropriate to the wider agenda that the science communication is now addressing'. In many countries, and at the European level, funding schemes and policy documents shifted their keywords from 'public awareness of science' to 'citizen engagement'; from 'communication' to 'dialogue'; from 'science *and* society' to 'science *in* society'. Initiatives have flowered that are aimed at eliciting public input on science and technology issues, and decision-making about science and technology. A notion of 'knowledge co-production' has been introduced by scholars to describe intense forms of participation of non-experts in the definition and accreditation of scientific knowledge – as when patients' organisations actively contribute to defining the priorities of medical research, or when citizens' groups gather epidemiological data that lead experts to rethink the cause of a certain pathology (Brown and Mikkelsen 1990). These forms have been interpreted as representing a major change not only with regard to the deficit model, but also with regard to its sociological critiques. According to Callon (1999), for instance, the critical version of public understanding of science – as reflected in the dialogic option – shifts the priority from 'the education of a scientifically illiterate public' to the need and right of the public to participate in the discussion, on the assumption that 'lay people have knowledge and competencies which enhance and complete those of scientists and specialists'. However, both models are seen as sharing 'a common obsession: that of demarcation. [The first model], in a forceful way, and [the second model], in a gentler, more pragmatic way, deny lay people any competence for participating in the production of the only knowledge of any value: that which warrants the term "scientific"' (ibid. 89). On this basis, the need has been invoked for another, more substantial shift to a model of knowledge co-production in which non-experts and their local knowledge can be conceived as neither an obstacle to be overcome by virtue of appropriate education initiatives (as in the deficit model), nor an additional element that simply enriches professionals' expertise (as in the critical–dialogical model), but rather as essential for the production of knowledge itself. Expert and lay knowledge are not produced independently in separate contexts to encounter each other later; rather, they result from common processes carried forward in 'hybrid forums' in which specialists and non-specialists can interact (Callon et al. 2001).

Does the change of keywords actually reflect a change in the practice and understanding of science communication? Or is it – as some scholars have suggested – in many cases a reappearance of the traditional, deficit model in a new guise (Stilgoe et al. 2005; Trench 2006)? How are these changes redefining, if ever, the role of science communication? Which theoretical model(s) can best help us interpret this changing scenario? Or, to cite another scholar, 'how dead is the deficit model?' (Trench 2006).

To answer these questions, I suggest that we first need to pay attention to the issue of context. One of the lessons from the 'sociological turn' of science communication studies is that public communication of science cannot be understood in a vacuum; rather, it should always be viewed not only in the context of expert/citizen interactions, but also in the broader context of science in society.

This apparently simple recommendation has several significant implications. One is that we cannot straightforwardly apply models of science communication (such as a diffusionist, popularisation notion of science communication), largely developed within the context of a science performed by relatively few state-based institutions, to a science characterised by pervasive relationships with the markets, global outlook and a strong public relations push (for which scholars have coined the label 'PUS inc.'; Bauer and Gregory 2007). Moreover, contemporary science is increasingly challenging the very notion of a sharp distinction between producers and users of knowledge, which rests at the basis of a diffusionist, deficit, transfer vision of science communication.[5] Companies, environmental organisations and patients' groups have established themselves as legitimate sources and providers of science communication.

A feature of the contemporary science in society context is also its intrinsic heterogeneity and fragmentation: communication is subject to the contradictory pressures of knowledge privatisation and commodification, open access and sharing of research results, and citizens' demands for greater involvement. All this makes implausible the use of a single science communication model to account for the varieties of contemporary expert/public configuration.

Table 5.1 sets out three key models of expert/public interaction – deficit,[6] dialogue and participation[7] – together with their vision of communication and their broader ideological contexts. These models should be conceived as ideal types, rather than as mutually exclusive categories. Most communicative situations would have to be described by a combination of the three models. In this framework, the deficit model does not need to disappear: it becomes the default, 'zero degree' of expert/public interaction processes. This is why it is important to distinguish the many different facets of such a model. While there are strong cases for dropping its expectation that public scepticism can be overcome by injecting knowledge, its top-down, transfer vision of communication may be a reasonable proxy to describe situations characterised, for instance, by a

Table 5.1 A multi-model framework of science communication (adapted from Trench 2006)

Communication model	*Emphasis*	*Dominant versions in science communication*	*Aims*	*Ideological contexts*
Transfer Popularisation One-way, one-time	Content	Deficit	Transferring knowledge	Scientism Technocracy Rhetoric of the knowledge economy
Consultation Negotiation Two-way, iterative	Context	Dialogue	Discussing implications of research	Social responsibility Culture
Knowledge co-production, deviation Multi-directional, open-ended	Content and context	Participation	Setting the aims, shaping the agenda of research	Civic science Democracy

low degree of public mobilisation, on science issues that have relatively low public resonance.[8] Over time, public/expert interaction with regard to a certain issue may move across models and their combinations: for instance, an emerging topic such as nanotechnology may lend itself to deficit-like communication in its initial stages, and later become the subject of public consultation/mobilisation; knowledge produced on a rare genetic pathology in situations of intense interaction between experts and non-experts may subsequently become the focus of a deficit-like communication initiative. Studies highlighting the connection between increase in the public salience of a certain science issue – or even in the level of knowledge – and mounting concern on the part of the public (Mazur 1981; Bucchi and Neresini 2002) might have actually grasped the 'tip of the iceberg' of these shifting configurations.

Coherence between communication patterns and the aims and ideological contexts deserves particular attention, as it may also help to clarify why institutions such as the European Commission have encountered difficulties in matching their claims for public participation in science and technology. A participatory, co-production approach to science communication appears difficult to couple with the emphasis on technocracy and rhetoric of the knowledge economy that form the basis of much EU policy strategy in the area of research, and rather lends itself to more traditional, deficit-transfer communication strategies (Trench 2006). Unlike deficit configurations, participation is also, by definition, multidirectional, open-ended and potentially subject to conflict. Some degree of apprehension for this open-endedness may be regarded as a key factor accounting for the sometimes resurgent temptation, on the part of research bodies and other institutions, to 'tame' unruly public participation through formal initiatives, or bluntly preaching dialogue and participation while practising the deficit. More generally, a continuous tension exists between opening up the black box of deficit communication for participation and, instead, putting participation back into the deficit box, with groups and institutions publicly struggling to impose their communicative definition of the situation – deficit, dialogue or participatory-like. A meta-level of science communication can be imagined, in which actors are constantly engaged to define (in participatory, dialogic or deficit form) the configuration of their interaction on a certain issue.

A communication pattern should also not necessarily be overlapped with the aims and interests of a specific category of actors. Research and policy institutions may (in a deficit-like communicative fashion) promote dialogic/participatory situations; citizens may contribute (in a dialogic/participatory fashion) to relegate into the deficit realm an issue on which they have little interest in participating, or on which they feel comfortable reducing their role to quasi-passive spectators of knowledge as channelled by experts for their own cultural benefit, aesthetic appreciation or entertainment.

In this light, rather than 'which model of science communication accounts best' for expert–public interactions, one of the key sociological questions becomes 'under what conditions do different forms of public communication of science emerge?'

While a detailed analysis of such conditions would require a treatment of its own, a tentative list could, in principle, include:

- the degree of public salience of a certain science issue;
- the level of public mobilisation on that and neighbouring issues;

- the visibility and credibility of science institutions and actors involved;
- the degree of controversy/disagreement among science experts, as perceived by the public;
- the degree of institutionalisation and the stability of professional boundaries in the science field of concern;
- the degree of social consensus on the overarching political and cultural context of science issues.

It may be expected, for instance, that an issue in the field of particle physics, with low public impact and mobilisation, little controversy among experts, propelled by visible research institutions, in a context in which understanding of the fundamental laws of nature is a socially shared and undisputed aim, may lend itself to a deficit-like pattern in which the public is invited and willing to appreciate the spectacle of science's achievements. Likewise, an issue such as genetically modified organisms, touching many publicly relevant themes including food, safety, biodiversity and resource distribution, with a certain amount of experts' disagreement as publicly perceived, propelled by corporate actors in a context highly sensitive, alerted and mobilised to questions of environment and globalisation, was unlikely to be containable in the deficit box. However, variations in the above-mentioned – and other potential – conditions may be reflected in a significant redefinition of the communication pattern. If an astrophysics result is framed as 'the Holy Grail of cosmology', as happened with the discovery in 1992 of radioactivity in the outer reaches of the known universe, taken to represent the echo of the Big Bang at the origin of the universe, the situation may slide into a more dialogic, open communication pattern in which the very boundaries between science and religion may be at stake (Miller 1994; Bucchi 2000).

It should be emphasised that the social, political and cultural contexts have a bearing not only on the introduction of new knowledge by the experts. Emerging trends in popular discourse can give a completely different status and meaning to already existing scientific results, turning a transfer-deficit situation into an intense communicative short-circuiting. Despite a significant advance in human cloning announced by a team of scientists in 1993, cloning was not an issue in countries such as Italy until the announcement of Dolly established a connection to a debate that had developed over issues such as embryos, in vitro fertilisation and abortion (Neresini 2000).

The broader political context may also be decisive in setting the scene for communicative interaction. Switzerland's or Scandinavia's tradition of civic participation is reflected in the relevance given to that participation with regard to science, to the point of being incorporated into legislative prescription and dedicated institutional agencies (e.g. Joss and Bellucci 2002).

Some general historical trends can be identified in the variations of these conditions. For instance, it is hard to deny that the increasing level of general education among citizens of many countries, or the expanded potential access to science information through the internet, have made participatory configurations more frequent and accessible today, particularly in areas such as biomedicine and the environment (Nowotny et al. 2001; Chapter 13 in this volume). Other broad trends may include the increasingly pervasive role of the media in questioning not only policy decisions on science but more specifically the connection between expertise and policy making; and the rising demand for public participation as part of more general criticism of the capacity of traditional democracies to represent and include citizens' points of view when addressing global challenges, with crucial decisions being more and more taken at levels not directly subject to citizens' influence – the so called 'democratic deficit' that is frequently a matter of concern with regard to, for instance, European or international institutions (Andersen and Burns 1996; Levidow and Marris 2001).

Other conditions may be much less stable. Several studies in sociological and historical perspective suggest, for instance, that the inclination of scientists to open up their communicative boundaries to non-experts is not a new, nor a steadily rising phenomenon, but could rather be described in terms of alternating cycles of openness and closure (deviation and popularisation) in a sort of pendular movement (Hirschman 1982). The consequences of these conditions seem far from straightforward.

For instance, when researchers mobilise in the public arena to protest against budget cuts or against state regulation of certain research fields, or simply advocate greater public concern with science, they may contribute to a growing public perception of scientific expertise as interest-laden, thus damaging the credibility of traditional decision-making arrangements that involve only experts and policy-makers (Bucchi and Neresini 2004). This, in turn, suggests an ironic and somewhat paradoxical generalisation of the above-mentioned 'open-endedness': citizens' pressures for more participation, which have contributed to undermining the deficit approach, may have been stimulated, among other things, by scientists' advocacy of that self-same approach.

On this view, one should also resist the temptation to interpret the different analytical models of interactions among experts and the public as a chronological sequence of stages in which the emerging forms obscure the previous ones, with the dialogue version obliterating the deficit one, or the participatory version substituting for the dialogue one. The interpretive framework proposed here seeks to account for the simultaneous coexistence of different patterns of communication that may coalesce, depending on specific conditions and on the issues at stake.

Communication should not be reified as a circumscribed, static event, nor as a prerogative that can be switched on and off at will. Rather, it should be viewed as a process that fluidly assumes different contingent configurations. A certain notion of the relationship between professional experts and the public – for instance, as segregated categories in the deficit model, or as inextricably intertwined as in the co-production model – is in itself a result of, and not a precondition for, the struggles, negotiations and alliances taking place in those configurations.

This theoretical framework certainly does not provide the science communicator with instructions as simple and appealing as those offered by the transfer/deficit approach; no easy 'switch' – to borrow another term from contemporary genetics research – to press (e.g. 'more communication!', 'focus the target!' 'clarify the message!') in order to produce the desired outcome among the public. Nor does it support the expectation that the aims of the 'old' deficit approach may finally be fulfilled by upgrading to the next 'communication fix', be it called dialogue or participation. The present framework eventually makes the process of public communication of science – and thereby the activities in which science communication practitioners are routinely engaged – more relevant, not only as a means to achieve certain objectives, but also as a central space in which to understand (and participate in) the interacting transformations of both science and public discourse. In this perspective, communication is not simply a technical tool functioning within a certain ideology of science and its role in economic development and social progress, but has to be recognised as one of the key dynamics at the core of those co-evolutionary processes (Nowotny et al. 2001; Jasanoff 2004, 2005), redefining the meanings of science and the public, knowledge and citizenship, expertise and democracy.

Notes

1 Cf. Lewenstein (1995a); Bucchi and Mazzolini (2003); Stephens (2005). Casadei (1994), for example, has conducted comparative lexical analyses of popular science texts, textbooks and specialist articles on physics, finding similar levels of technicality in the three genres, with the maximum level not in the specialist texts but in the textbooks.

2 To draw another analogy, deviation with respect to popularisation can be considered equivalent to a scientific revolution with respect to normal science (Kuhn 1962).

3 The pervasive influence of the transfer metaphor has been seen in relation to its being, to some extent, embedded in languages such as English – lacking expressions to describe communication processes other than those related to 'transfer' and 'transportation' of messages (Reddy 1979).

4 In this sense, boundary objects are not so different from what the actor-network theory identifies as 'obligatory passage points' in translating interests and enrolling supporters for a scientific claim (Latour 1987), or what Moscovici (1961) locates at the heart of a social representation (its 'zero degree').

5 'Post-academic science' and 'mode-2 science' are some of the labels used by scholars to indicate these emerging configurations of research in contemporary society (Gibbons et al. 1994; Ziman 2000; Nowotny et al. 2001)

6 As has been noted, 'deficit' refers to a specific element of the model, the emphasis on the knowledge asymmetry between experts and the public as a basis and rationale for the communicative interaction. It would be more accurate to refer to this model as a 'diffusionist' conception that, beyond the deficit element, incorporates a notion of communication as unproblematic one-way transfer, having no impact on the processes of knowledge production (popularisation). However, as 'deficit' has become the standard label for the whole constellation among policy-makers and scholars, I use it hereafter with the same general meaning.

7 Public participation in science may be defined broadly as 'the diversified set of situations and activities, more or less spontaneous, organised and structured, whereby non-experts become involved, and provide their own input to, agenda setting, decision-making, policy forming and knowledge production processes regarding science' (Callon et al. 2001; Rowe and Frewer 2005; Bucchi and Neresini 2007). Under such a broad definition, participation encompasses not only formal participatory initiatives promoted by a certain sponsor (such as consensus conferences), but also a broad range of situations including public protests, referendum voting and patient initiatives. When seen from the point of view of experts/insiders, and of the consequences for specialist discourse, a participation pattern of interaction can be said to incorporate a deviation element.

8 Different reappraisals of the deficit model are given by Sturgis and Allum (2004); Dickson (2005).

Suggested further reading

Bucchi, M. (1998) *Science and the Media. Alternative Routes in Scientific Communication*, London and New York: Routledge.

Bucchi, M. and Neresini, F. (2007) 'Science and public participation', in Hackett, E. et al. (eds) *Science and Technology Studies Handbook*, Cambridge, MA: MIT Press, 955–1001.

Cooter, R. and Pumfrey, S. (1994) 'Science in popular culture', *History of Science*, 32: 237–67.

Fleck, L. (1935) *Entstehung und Entwicklung einer wissenschaftliche Tatsache* (Eng. tr. *Genesis and Development of a Scientific Fact*, Chicago, IL: University of Chicago Press, 1979).

Shinn, T. and Whitley, R. (1985) (eds) *Expository Science. Forms and Functions of Popularization*, Dordrecht: Reidel.

Other references

Andersen, S. and Burns, T. (1996) 'The European Union and the erosion of parliamentary democracy: a study of post-parliamentary governance', in Andersen, S. and Eliassen, K. A. (eds) *European Union – How Democratic is It?*, London: Sage, 227–51.

Balmer, B. (1990) 'Scientism, science and scientists', research paper, Science Policy Research Unit, University of Sussex, UK.

Bauer, M. and Gregory, J. (2007) 'From journalism to corporate communication in post-war Britain', in Bucchi, M. and Bauer, M. (eds) *Journalism, Science and Society: Science Communication between News and Public Relations*, London: Routledge: 33–52.

Brown, P. and Mikkelsen, E. (1990) *No Safe Place: Toxic Waste, Leukemia, and Community Action*, Berkeley, CA: University of California Press.

Bucchi, M. 1996 'When scientists turn to the public: alternative routes in science communication', *Public Understanding of Science*, 5: 375–94.

—— (1997) 'The public science of Louis Pasteur: the experiment on anthrax vaccine in the popular press of the time', *History and Philosophy of the Life Sciences*, 19: 181–209.

—— (1998) *Science and the Media. Alternative Routes in Scientific Communication*, London and New York: Routledge.

—— (2000) 'A public explosion: Big Bang in the UK daily press', in Dierckes, M. and von Grote, C. (eds) *Between Understanding and Trust: The Public, Science and Technology*, Reading: Harwood.

Bucchi, M. and Mazzolini, R. G. (2003) 'Big science, little news: science coverage in the Italian daily press, 1946–1997', *Public Understanding of Science*, 12: 7–24.

Bucchi, M. and Neresini, F. (2002) 'Biotech remains unloved by the more informed', *Nature*, 416: 261.

—— (2004) 'Why are people hostile to biotechnologies?' *Science*, 304: 1749.

—— (2007) 'Science and public participation', in Hackett, E. et al. (eds) *Science and Technology Studies Handbook*, Cambridge, MA: MIT Press, 955–1001.

Callon, M. (1999) 'The role of lay people in the production and dissemination of scientific knowledge', *Science, Technology & Society*, 4: 81–94.

Callon, M., Lascoumes, P. and Barthe, Y. (2001) *Agir dans un monde incertain: Essai sur la démocratie technique*, Paris: Seuil.

Casadei, F. (1994) 'Il lessico nelle strategie di presentazione dell'informazione scientifica: il caso della fisica', in De Mauro, T. (ed.) *Studi sul trattamento linguistico dell'informazione scientifica*, Roma: Bulzoni, 47–69.

Clemens, E. (1994) 'The impact hypothesis and popular science: conditions and consequences of interdisciplinary debate', in Glen, W. (ed.) *The Mass-Extinction Debates: How Science Works in a Crisis*, Stanford, CA: Stanford University Press.

Cloître, M. and Shinn, T. (1985) 'Expository practice: social, cognitive and epistemological linkages', in Shinn, T. and Whitley, R. (eds) *Expository Science. Forms and Functions of Popularization*, Dordrecht: Reidel, 31–60.

Collins, H. M. (1987) 'Certainty and the public understanding of science: science on television', *Social Studies of Science*, 17: 689–713.

Cooter, R. and Pumfrey, S. (1994) 'Science in popular culture', *History of Science*, 32: 237–67.

Dickson, D. (2005), 'The case for a "deficit model" of science communication', SciDev.Net, 28 June 2005.

Dunwoody, S. and Scott, B. (1982) 'Scientists as mass media sources', *Journalism Quarterly*, 59: 52–9.
Epstein, S. (1996) *Impure Science: AIDS, Activism and the Politics of Knowledge*, Berkeley, CA: University of California Press.
Fleck, L. (1935) *Entstehung und Entwicklung einer wissenschaftliche Tatsache* (Eng. tr. *Genesis and Development of a Scientific Fact*, Chicago, IL: University of Chicago Press, 1979).
Goodell, R. (1977) *The Visible Scientists*, Boston, MA: Little Brown.
Gibbons, M., Limoges, C., Nowotny, H., Schwartzman, S., Scott, P. and Trow, M. (1994) *The New Production of Knowledge: Dynamics of Science and Research in Contemporary Societies*, London: Sage.
Gregory, J and Miller, S. (1998) *Science in Public. Communication, Culture, and Credibility*, London: Plenum.
Grmek, M. D. (1989) *Histoire du SIDA*, Paris, Payot.
Grundmann, R. and Cavaillé, J. P. (2000) 'Simplicity in science and its publics', *Science as Culture*, 9: 353–89.
Hansen, A. (1992) 'Journalistic practices and science reporting in the British press', *Public Understanding of Science*, 3: 111–34.
Hilgartner, S. (1990) 'The dominant view of popularization', *Social Studies of Science*, 20: 519–39.
Hirschman, A. (1982) *Shifting Involvements. Private Interest and Public Action*, Princeton, NJ: Princeton University Press.
Jacobi, D. (1987) *Textes et Images de la Vulgarisation Scientifique*, Bern: Peter Lang.
Jasanoff, S. (2004) *States of Knowledge: The Co-production of Science and Social Order*, London: Routledge.
—— (2005) *Designs on Nature. Science and Democracy in Europe and the United States*, Princeton, NJ: Princeton University Press.
Joss, S. and Bellucci, S. (eds) (2002) *Participatory Technology Assessment: European Perspectives*, London: Centre for the Study of Democracy.
Kuhn, T. S. (1962) *The Structure of Scientific Revolutions*, Chicago, IL: Chicago University Press (2nd edn 1969).
Latour, B. (1987) *Science in Action*, Cambridge, MA: Harvard University Press.
Levidow, L. and Marris, C. (2001) 'Science and governance in Europe: lessons from the case of agricultural biotechnology', *Science and Public Policy*, 28: 345–60.
Lewenstein, B. (1995a) 'Science and the media', in Jasanoff, S. et al. (eds) *Handbook of Science and Technology Studies*, Thousand Oaks, CA: Sage: 343–59.
—— (1995b) 'From fax to facts: communication in the cold fusion saga', *Social Studies of Science*, 25: 403–36.
Lewontin, R. (1996) 'In the blood', *New York Review of Books*, 23 May: 31–2.
Macdonald, S. and Silverstone, R. (1992) 'Science on display: the representation of scientific controversy in museum exhibition', *Public Understanding of Science*, 1: 69–87.
Mazur, A. (1981) 'Media coverage and public opinion on scientific controversies', *Journal of Communication*, 31: 106–15
Michael, M. (2002) 'Comprehension, apprehension, prehension: heterogeneity and the public understanding of science', *Science Technology & Human Values*, 27: 357–78.
Miller, S. (1994) 'Wrinkles, ripples and fireballs: cosmology on the front page', *Public Understanding of Science*, 3: 445–53.
Moscovici, S. (1961) *La psychanalyse, son image, son public*, Paris: Puf.
Neresini, F. (2000) 'And man descended from the sheep: the public debate on cloning in the Italian press', *Public Understanding of Science*, 9: 359–82.
Nowotny, H., Scott, P. and Gibbons, M. (2001) *Re-Thinking Science. Knowledge and the Public in an Age of Uncertainty*, Cambridge: Polity Press.
Pais, A. (1982) *Subtle is the Lord...: the Science and Life of Albert Einstein*, New York: Oxford University Press.

Peters, H. P.(1995) 'The interaction of journalists and scientific experts: co-operation and conflict between two professional cultures', *Media Culture & Society*, 17: 31–48.

Phillips, D. M. (1991) 'Importance of the lay press in the transmission of medical knowledge to the scientific community', *New England Journal of Medicine*, 11 Oct: 1180–3.

Raichvarg, D. and Jacques, J. (1991) *Savants et Ignorants. Une Histoire de la Vulgarisation des Sciences*, Paris: Seuil.

Reddy, M. (1979) 'The conduit metaphor. A case of frame conflict in our language about language', in Ortony, A. (ed.) *Metaphor and Thought*, Cambridge: Cambridge University Press, 284–324.

Rowe, G. and Frewer, L. J. (2005) 'A typology of public mechanisms', *Science, Technology & Human Values*, 30: 251–90.

Shinn, T. and Whitley, R. (1985) (eds) *Expository Science. Forms and Functions of Popularization*, Dordrecht: Reidel.

Stephens, L. F. (2005) 'News narratives about nano S&T in major US and non-US newspapers', *Science Communication*, 27: 175–99.

Stilgoe, J., Wilsdon, J. and Wynne, B. (2005) *The Public Value of Science*, London: Demos.

Sturgis, P. J. and Allum, N. C. (2004) 'Science in society: re-evaluating the deficit model of public attitudes', *Public Understanding of Science*, 13: 55–74.

Trench, B. (2006) 'Science communication and citizen science: how dead is the deficit model?', paper presented at PCST9 Conference, Seoul, 17–19 May 2006.

Turney, J. (1998) *Frankenstein's Footsteps. Science, Genetics and Popular Culture*, New Haven, CT: Yale University Press.

Whitley, R. (1985) 'Knowledge producers and knowledge acquirers', in Shinn, T. and Whitley, R. (eds), *Expository Science. Forms and Functions of Popularization*, Dordrecht: Reidel, 3–28.

Wynne, B. (1989) 'Sheepfarming after Chernobyl: a case study in communicating scientific information', *Environment Magazine*, 31: 10–39.

—— (1995) 'Public understanding of science', in Jasanoff et al. (eds) *Handbook of Science and Technology Studies*, Thousand Oaks, CA: Sage: 361–89.

Ziman, J. (2000) *Real Science. What It Is, and What It Means*, Cambridge: Cambridge University Press.

Zola, E. (1871) *La Fortune des Rougon* (edn 1981, Flammarion, Paris).