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Science in the news: a study of reporting genomics

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Scientists and academicians in the field of science writing agree that context and method are important components of research to be reported. This ideal is balanced by science journalists who try to relay findings with a minimum of complex and potentially confusing facts. Here, a specific report on genomics is traced from its original source in a scientific journal through to popular press publications. These data were examined in the context of previously published findings that have shown that the reader needs a clear understanding of the context of reported results to make an informed judgment about their meaning. This study reveals that these five reports, ranging from research article to popular press news article, differ in *what* is said rather than *how* it is said. This is surprising given the premise that in science reporting, the primary role of the journalist is to translate science into non-scientific language.

1. Introduction

A 2001 Policy Perspective in *Public Understanding of Science* raised the question of how the public is being informed about ongoing research in the sciences. In it, the authors review the state of science communication, which focuses on providing basic science knowledge, and contrast it with the current worldwide research environment that is exploring new territory at a frenetic pace. They draw a distinction between previously established knowledge of science and ongoing research, and propose the need for public information that goes beyond translating established knowledge and presenting scientific investigation as a simple, linear process, rather than acknowledging the circuitous path it often takes (Field and Powell, 2001).

John Durant, professor of the public understanding of science and co-director of the United Kingdom's first public understanding of science survey, proposed a tripartite model for the public understanding of science: "knowing a lot of science," "knowing how science works," and "knowing how science *really* works" (cited in Gregory and Miller, 1998: 90, emphasis added)—the facts of science, the research methods of science, and the sociology of science. The facts of science can be thought of as what science has discovered about the functioning of organisms and the universe—for example, how the digestive system works or what the sun is made of. The research methods of science are how science operates on a day-to-day basis, how hypotheses are generated and revised. The sociology of science refers

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to the way in which the scientific community operates; for instance, how research efforts secure funding, how theories come into vogue, are judged, and are accepted or rejected.

Conveying this lesser-known culture of science to the public may help the audience to comprehend how new scientific discoveries are made and could help them place new findings in the context of previously reported work. These points are highlighted in studies of audience comprehension of science and reaction to scientific reports. In studies of audience comprehension of news stories involving science, Carol Rogers identifies two major problems encountered by focus groups: lack of information and of context. Participants dealing with stories about AIDS drugs wanted more detailed information and more information about side effects and economic issues: "They wanted to know where this new information fit into the bigger picture of what came before and what was next. Without such context, they had difficulty making sense of the information and deciding just how important it was in the larger scheme of things" (Rogers, 1999: 191).

Similarly, participants given stories about global warming wanted to know about the backgrounds of the experts cited, the effects of global warming, the role human activities played—more information, more context, more details. In addition, they "seemed to be looking primarily for the evidence that had formed the basis of the . . . statement" (Rogers, 1999: 191).

Other problems identified by Rogers can be classified into categories based on the first two, i.e., problems conveying information and problems conveying context.

Marianne Pellechia found, in a 1997 study of science news content in "prestige newspapers"—*The New York Times*, *The Chicago Tribune*, and *The Washington Post*—that the percentage of science coverage over the periods analyzed (1966–1970, 1976–1980, 1986–1990) had increased, but the type of content was not much changed. She writes, "articles frequently omitted methodological and contextual information, features most often mentioned as critical for a complete journalistic account of science" (Pellechia, 1997: 49). Pellechia identifies the following common errors found in studies of media reports on scientific topics in her opening survey:

> omission of qualifying statements (found in 60 percent of the accounts), a lack of discussion of the methodology followed (48 percent of the accounts), a change of emphasis (45 percent of the accounts), and an overstatement of the generalizability of the data (36 percent of the accounts). (Singer, 1990, cited in Pellechia, 1997: 51)

Pellechia also noted that previous research in the field of the reported finding is often ignored by science writers (Pellechia, 1997). Gregory and Miller (1998) observe that there has not been much evidence that contextual information really makes a difference to a reader's understanding of science; Pellechia acknowledges questions about the utility of methodological information in specific cases, but overwhelmingly supports the necessity of giving a comprehensive account.

In an article titled "Effective explanation of uncertain and complex science," Rowan (1999) offers suggestions for journalists dealing with science, beginning with a consideration of some myths she identifies as being present in science communication.

The first myth is that science is a collection of facts that scientists spot and that journalists convey to the public so news audiences can apply them to their lives (Rowan, 1999). Rowan disagrees with the idea that science is a collection of facts; she presents, instead, a vision of science as a puzzle-solving process. She goes on to state that when journalists report science news, they should include audiences in this puzzle-solving by reporting the reasoning that supports or questions the findings (Rowan, 1999). She asserts

that audiences are not well served when scientific findings are reported without the reasoning that led to those findings (Rowan, 1999).

Rowan suggests that journalists find out, and presumably convey, "what evidence, reasoning or testing supports a finding," "what bugs, frustrates, or impresses scientists about their finding" and "what parts of the puzzle remain unsolved" (Rowan, 1999: 202). The recommendations of experts in the field of science communication and the recommendations of panels that aim to improve scientific reporting are similarly applied to the data we present here. These data show how the news stories analyzed in this study did not include the reasoning, context, or methods that led to the scientific findings being reported.

This study examines five representations of research: the primary journal article published in a peer-reviewed science journal, a review from the same journal, a press release and web-published technical report from the research institution where the finding was made, and two newspaper reports of the work. In an effort to examine a wide range of sources from the scientific to the popular press, we analyzed the content as presented in the original source and tracked the story from the original report through sources such as the Massachusetts Institute of Technology's (MIT) *Tech Talk* and finally followed it to large, general-audience papers such as *USA Today* and *Newsday*. The data presented here are in the form of a specific analysis, which supports and extends previously published findings in the field of science communication (Pellechia, 1997).

2. Results

Case study: genomics and cancer

A paper entitled "Genomic analysis of metastasis reveals an essential role for RhoC" was published in the 3 August 2000 issue of *Nature*, a peer-reviewed interdisciplinary science journal. In it, Edwin Clark and collaborators at MIT describe the use of sweeping genetic analyses—genomic analysis—of mouse and human melanoma cells, to find out which genes are involved in the process of turning a benign tumor cell into a metastatic one (Clark et al., 2000).

Cancer is the uncontrolled proliferation of cells, i.e., cells dividing inappropriately, and forming the clumps of cells we call tumors. When a tumor forms but does not spread to other parts of the body, it is "benign" and can be surgically removed. When tumor cells metastasize, they undergo rapid growth and spread to other parts of the body and become "malignant," and difficult to eradicate. Melanoma, cancer of the skin, has proved to be a useful model for the study of how and why tumor cells metastasize.

The role of RhoC

Nature has its contributors write a concise introductory paragraph "of no more than 180 words (ideally shorter) which should both introduce the work and provide a non-technical summary" (*Nature*, 1999b; see also *Nature*, 1999a). Since *Nature* is an interdisciplinary journal, the paragraph is aimed at scientist–readers who do not have specialized knowledge of the field. The introductory paragraph (Table 1) is thus worth a close look, since it both introduces and sums up the most important points of the work.

The first three sentences in the paragraph introduce the topic and frame it by giving the broader context of the work, situating it within the current body of knowledge:

- The most damaging change during cancer progression is the switch from a locally growing tumour to a metastatic killer.

Table 1. Clark et al. introductory paragraph

The most damaging change during cancer progression is the switch from a locally growing tumour to a metastatic killer. This switch is believed to involve numerous alterations that allow tumour cells to complete the complex series of events needed for metastasis. Relatively few genes have been implicated in these events. Here we use an *in vivo* selection scheme to select highly metastatic melanoma cells. By analysing these cells on DNA arrays, we define a pattern of gene expression that correlates with progression to a metastatic phenotype. In particular, we show enhanced expression of several genes involved in extracellular matrix assembly and of a second set of genes that regulate, either directly or indirectly, the actin-based cytoskeleton. One of these, the small GTPase RhoC, enhances metastasis when overexpressed, whereas a dominant-negative Rho inhibits metastasis. Analysis of the phenotype of cells expressing dominant-negative Rho or RhoC indicates that RhoC is important in tumour cell invasion. The genomic approach allows us to identify families of genes involved in a process, not just single genes, and can indicate which molecular and cellular events might be important in complex biological processes such as metastasis.

Source: Clark, Edwin A. et al. (2000).

- This switch is believed to involve numerous alterations that allow tumour cells to complete the complex series of events needed for metastasis.
- Relatively few genes have been implicated in these events. (Clark et al., 2000)

As will be seen, this research-centered model of introduction and introductory context is also used in the journal review and in the institutional press release.

The researchers go on to talk about the work itself, i.e., the methods used in the study:

- Here we use an *in vivo* selection scheme to select highly metastatic melanoma cells. (Clark et al., 2000)

They later explain that this selection scheme involved injecting melanoma cells from humans and mice into the tails of host mice, and extracting metastatic cells from the mouse lungs. Presumably, only the most highly metastatic cells would have been able to travel the distance and establish a lineage so far away.

- By analysing these cells on DNA arrays, we define a pattern of gene expression . . .
- In particular, we show enhanced expression of several genes involved in . . . matrix assembly and of a second set of genes that regulate, either directly or indirectly, the . . . cytoskeleton. (Clark et al., 2000)

DNA array, or microarray, technology allows thousands of genes to be screened at a time, and was used here to analyze the genetic makeup of the cells. Data obtained from this analysis were used to identify genes that were more highly expressed in highly metastatic cells than in poorly metastatic cells; this helped identify genes that were involved in turning the cell metastatic. The researchers were able to also identify the functions of these genes, and thus speculate on the biological sense of the findings, or how a cell's genes affected its overall function.

- One of these . . . RhoC, enhances metastasis when overexpressed, whereas a dominant-negative Rho inhibits metastasis. . . . (Clark et al., 2000)

Then the most striking new knowledge is stated. Significantly, these findings about RhoC are not presented as bald fact; the reasoning behind the conclusions is integral to those

conclusions being made, therefore the logic is embedded in the reporting of the results. In order for RhoC to play a causal role in the progression of the cell to metastasis, not only must it enhance metastasis when it is present; the lack of it (in the so-called dominant-negative mutant) must inhibit the process in some way. This is exactly what the researchers found, and these results *together* implied that RhoC is an essential factor and is required for metastasis to occur.

The researchers end with more context, this time in terms of the method and its usefulness:

> - The genomic approach allows us to identify families of genes involved in a process, not just single genes, and can indicate which molecular and cellular events might be important in complex biological processes such as metastasis. (Clark et al., 2000)

This "genomic approach" is premised on extensive DNA sequence information and microarray technology, both concerns of the Human Genome Project, which was in many ways quite a public relations coup for science. This melanoma study was one of the early examples of tangible results to be had from the new methods, and the significance of the findings was both in the new knowledge gained and in the paths that were taken to get to it. Science is very much about method, and hence, the efficacy of methods is here noted.

The introductory paragraph shows the following to be the main points of the work as reported in the scientific paper: the context, the methods, the new knowledge obtained, the logical proof of the results, and the demonstration of success of a new analytical method.

From the primary report to scientific publications and the lay press

The Clark et al. paper was reviewed in the same issue of *Nature*, in an article titled "Molecular switches in metastasis," by Anne Ridley (2000). The day before publication of the journal, MIT issued a press release, "MIT researchers identify the genes responsible for cancer cells' ability to migrate within the body" (MIT, 2000). Within the same two days, *USA Today* ran a story headlined "Genes linked to cancer's mobility: Human genome led to discovery," by Steve Sternberg (2000) and *Newsday* (New York) had a story titled "Genetic clues to cancer's spread: Study pinpoints why only some metastasize," by Delthia Ricks (2000a) (this story also ran in *The Seattle Times* (Ricks, 2000b); these are the same article, reprinted under a different headline. Ricks is a *Newsday* staff writer.

Introductions

The introductory material to each piece provides an indication of the nature and focus of each piece (see Table 2). The first five main ideas are considered here.

All five pieces open with some context: a sentence or two explaining the danger and significance of metastasis; all except the research paper provide a quick explanation of the term. Thereafter, they diverge, showing a clear distinction between science and non-science publications.

Review article

Clark et al. (2000) and their reviewer Anne Ridley (2000) present and set up their information in a strikingly similar way. In the Clark et al. paragraph, the researchers start with sentence 1, on the danger of metastasis (Table 2, A1). They then move to sentence 2 (Table 2, A2), which is about current knowledge about metastasis, i.e., its molecular basis.

Table 2. Opening ideas

A: Clark et al. (2000) (*Nature* paper)	B: Ridley (2000) (*Nature* review)	C: MIT (2000) (press release)	D: *Newsday/Seattle Times* (Delthia Ricks, 2000a, b)	E: *USA Today* (Steve Sternberg, 2000)
A1 The most damaging change during cancer progression is the switch from a locally growing tumour to a metastatic killer.	B1 For patients with solid tumours, the biggest threat to survival is metastasis—the spread of tumour cells from the original growth to other sites in the body.	C1 Researchers at MIT report in the August 3 issue of *Nature* that they have identified a single gene that lends some cancer cells the particularly deadly ability to break off a tumor and travel to other parts of the body.	D1 Using molecular data from the Human Genome Project, scientists have identified a gene that causes some cancer cells to break away from their original tumor and seed new tumors in distant sites.	E1 Researchers using data from the Human Genome Project report today that they have found a gene that prompts cancer cells to stray from their original site to distant parts of the body.
A2 The switch is believed to involve numerous alterations that allow tumour cells to complete the complex series of events needed for metastasis.	B2 For biologists studying cancer, a major challenge is to identify the underlying molecular changes that switch cells to a metastatic state, with the ultimate aim being to devise treatments that inhibit metastasis.	C2 This process, called metastasis, is responsible for 90 percent of cancer deaths.	D2 It is a discovery scientists are hailing as a significant advance in understanding the molecular mechanisms that underlie why cancer cells stray.	E2 That process, known as metastasis, causes 90% of cancer deaths.
A3 Relatively few genes have been implicated in these events.	B3 Previous research has concentrated on the contribution of individual genes to metastasis.	C3 If scientists can pinpoint which genes are essential for invasion and metastasis, they can use that information for better diagnosis and therapies.	D3 The consequences of that wanderlust, researchers estimate, ultimately lead to 90 percent of all cancer deaths.	E3 [Quote explaining metastasis/benign tumour; see Table 4, c]
A4 Here we use . . . By analysing these cells on DNA arrays, we show enhanced expression of several genes involved in . . .	B4 Now, gene-expression profiling, using high-density DNA microarrays, is revolutionizing our approach to studying cancer.	C4 [Quote] "I believe that invasion and metastasis are now ripe for concerted attack . . ."	D4 The study is one of two reported in today's issue of the journal *Nature* that focus on cancer's spread—metastasis—in malignant melanoma, a deadly form of skin cancer that will afflict more than 40,000 Americans this year.	E4 Genes play a role in every step of the process.
A5 The genomic approach allows us to identify families of genes involved in a process, not just single genes, and can indicate which molecular and cellular events might be important in complex biological processes such as metastasis.	—	C5 Using mouse and human models of melanoma, data from the Human Genome Project, DNA arrays and gene analysis software, Edwin A. Clark . . . sought to identify precisely which genes or sets of genes are responsible for regulating metastasis.	D5 The findings from both investigations hold promise of using gene-based data to stop the spread of cancer before it starts, medical experts say.	E5 Hynes' team studied one of the most feared forms of cancer, malignant melanoma. Using small glass slides with arrays of 10,000 known genes as detectors . . .

Sentence 3 (Table 2, A3) talks about previous work in this area. The review article does almost exactly the same thing. Sentence 1: the danger of metastasis, plus a definition of the term (Table 2, B1). Sentence 2: current knowledge of molecular changes, plus future applications of the research (Table 2, B2). Sentence 3: previous work done (Table 2, B3). The review packs a lot of information into a few sentences, but it is all clearly stated, and key concepts are concisely defined within the first three paragraphs (Table 3). The reviewer is writing for a non-specialist scientific audience. Though she uses scientific terms freely and comments specifically on experimental results and methods throughout her article, the reader is able to understand what she is saying without necessarily being an expert in cancer or molecular biology.

Technical Web news source and institutional press release

The MIT (2000) press release follows a similar model to the original paper and the review. Like the other two, it begins with why metastasis is important—it causes cancer death; what scientists know about metastasis—its molecular basis; what they are trying to do—identify genes; and why they should do this—possible treatment. The MIT release reverses the order of ideas slightly, with application (Table 2, C3) preceding research context (Table 2, C4) instead of following it. Unfortunately, the release is a little too jargon-laden for a piece intended for a general audience, and demonstrates the challenge of talking about the science without scaring the lay reader away.

What these three "science" pieces have in common is their subject, which is the new information obtained (about RhoC and other genes and proteins) and the methods used to obtain this information (*in vivo* selection and DNA microarrays). The findings are presented in terms of a past, current, and future body of knowledge about metastasis at the molecular level. The pieces present the new information in terms of the research efforts in this area. As was seen initially in the analysis of the Clark et al. paper, in all three pieces just considered, findings and methods take center stage.

News reports

In contrast to scientific or technical reports at the forefront of the newspaper reports are definitions and explanations about metastasis at the physiological level, which is a peripheral

Table 3. Ridley (*Nature* review) first three paragraphs

For patients with solid tumours, the biggest threat to survival is metastasis—the spread of tumour cells from the original growth to other sites in the body. For biologists studying cancer, a major challenge is to identify the underlying molecular changes that switch cells to a metastatic state, with the ultimate aim being to devise treatments that inhibit metastasis. Previous research has concentrated on the contribution of individual genes to metastasis. Now, gene-expression profiling, using high-density DNA microarrays, is revolutionizing our approach to studying cancer.

On page 532 of this issue, Clark *et al.* describe how they used this approach to identify several genes that are selectively upregulated in metastatic mouse and human melanoma cells compared with their non-metastatic counterparts. They find that, remarkably, overexpression of one of these genes—RhoC—can stimulate metastasis all by itself. Meanwhile, Bittner *et al.* (page 536 of this issue) have used microarrays to compare different subgroups of human melanoma, and also find a distinct pattern of gene expression in highly invasive melanoma cells.

In DNA microarrays, probes for the messenger RNA products of up to 10,000 different genes are present on a single 'chip', usually a glass slide. The chips are used to determine which of these genes are expressed (that is, which are transcribed into mRNA) in a selected cell type. This technology has already been used to classify cancers, such as leukaemia, according to their gene-expression profile.

Source: Ridley (2000).

issue in the "science" pieces. Although the openings to these news reports (Table 2) introduce the subject in a way similar to that of the "science" pieces, and throw in "real-world" statistics (Table 2, D2, D3, E4) to catch the reader's attention, and make it relevant to the reader's context and frame of reference, the pieces as a whole tend to stray from the specific research being reported.

News report A

The *USA Today* piece follows up the common lead (Table 2, sentences 1–2 in all pieces) with further explanation of what clinical metastasis is (Table 2, E3 and E4) and then reports on the experimental results (Table 4, d and e). It does so, however, without relating this molecular information to potential clinical applications (Table 4, e), or explaining how the Human Genome Project, which it mentions (Table 4, f), comes into play. After another paragraph about the dangers of melanoma and a paragraph about a related study, it closes as follows:

> The two teams took very different roads to nearly the same place. "Ours was a global search, theirs was a specific search, but we both drilled down the same pathways," says [the] lead investigator . . . (Table 4, i; Sternberg, 2000)

Table 4. *USA Today* full article

Gene linked to cancer's mobility: Human genome led to discovery
a Researchers using data from the Human Genome Project report today that they have found a gene that prompts cancer cells to stray from their original site to distant parts of the body.
b That process, known as metastasis, causes 90% of cancer deaths.
c "For a tumor to metastasize, its cells have to have lost growth control, but that's not enough," says lead researcher Richard Hynes, director of the Center for Cancer Research at the Massachusetts Institute of Technology. "If that were all that were wrong, we would call the tumor benign, and a surgeon could take care of it." Instead, tumor cells must burst free from their moorings, move to distant locations and become established there. Genes play a role in every step of the process.
d Hynes' team studied one of the most feared forms of cancer, malignant melanoma. Using small glass slides with arrays of 10,000 known genes as detectors, researchers exposed the genes to thousands of others taken from melanoma cells. The experiment revealed that malignant cells had 32 active genes that were not active in non-malignant cells.
e Tests in mice showed that one of the genes, RhoC, makes melanoma cells 50 times more invasive. Two other genes also appear to play supporting roles. One assembles a protein, fibrinectin, that enables wayward cancer cells to put down new roots. The other makes angiopoetin, a protein that helps establish the new tumor's blood supply. Each of the genes represents a target for melanoma treatments.
f The government-sponsored Human Genome Project is an international consortium of scientists that completed the rough draft of the human genetic blueprint in June. By using information from the human genome, researchers in the new study uncovered an aspect of cancer biology that was previously beyond the reach of science. "This approach is going to produce a flood of information that will improve the diagnosis and, eventually, therapy for cancer," Hynes says.
g This year alone, doctors will diagnose 50,000 cases of melanoma, and its incidence is rising by about 4% a year, according to the American Cancer Society. Highly curable if caught before it has spread, melanoma kills nearly 90% of patients within five years once it has metastasized.
h A separate study, by researchers at 11 laboratories worldwide, used a similar method to group melanoma patients by genetically profiling their tumor cells. That team was able to group patients by their patterns of gene activity and identify 200 genes that play a role in invasive melanoma cases.
i The result: The two teams took very different roads to nearly the same place. "Ours was a global search, theirs was a specific search, but we both drilled down the same pathways," says lead investigator Jeffrey Trent of the National Human Genome Research Institute in Bethesda, Md.
j Both reports appear in today's issue of the journal Nature.

Source: Sternberg (2000).

In this case, there seems to be a disjunction in content. In this piece, what "roads" the teams took and what "place" they reached had thus far seemed merely peripheral. The information that jumps out at you as you read the piece is the "90% of cancer deaths," "50,000 cases of melanoma," "one of the most feared forms of cancer," "an international consortium."

In other words, the way this article has been written, its message goes something like this: *Cancer death is caused by metastasis, which is caused by genes. Many scientists and the Human Genome Project have brought about new discoveries about these genes. Melanoma is very dangerous*. By the time we get to the conclusion quoted above, the reader is not sure what type of "search[es]" have been done, and what "pathways" are referred to, an important omission of both the methods and the context of the findings. We do not get the message, reading this report, that *Cancer death is caused by metastasis, which is caused by genes. Scientists recently used DNA sequence information and microarray technology, fruits of the Human Genome Project, to discover genes that contribute to causing metastasis, including a particular gene that "can stimulate metastasis all by itself"* (Ridley, 2000).

This latter story may be what both reporters (in news reports A and B) want to convey. However, they are also required to make the research accessible to the reader through an appeal to the emotions—what Aristotle calls *pathos* in the art of rhetoric, instead of through *logos*—an appeal based on the inherent logic of the argument (Penrose and Katz, 1998). The science is pared down to isolated facts rather than effectively translated with methodology and context included. The journalist is constrained by the readers' lack of scientific knowledge as well as by her/his editorial constraints.

The *USA Today* article does contain sufficient information (e.g., in Table 4, d and h) to understand the closing paragraph quoted earlier and get the message shown above. However, without the research being presented in context, i.e., in the frame of current and future work, there is no way for the reader to assess the scientific significance of the new findings.

News report B

The *Newsday* report is more focused than the *USA Today* piece, but also, delivers a general science lesson rather than reporting on the new research findings presented in the *Nature* study. The lead is followed up by a line about molecular understanding (Table 2, D2), and the next two sentences feature striking statistics about metastasis and melanoma deaths (Table 2, D3 and D4). Then possible future application of such research is noted (Table 2, D5). These introductory elements are the familiar few, and they parallel the "scientific" model more closely than the *USA Today* piece (news report A). While news report A is careful to specifically cite some of the findings of the study, though, news report B spends most of its time explaining physiological metastasis instead. News report B is more internally coherent because of this emphasis on metastasis at the physiological level, and the findings that are mentioned are better contextualized (e.g., "RhoC . . . sheds new light on the processes of having, losing and regaining adhesion"). We note also that in this article method is highlighted, with a discussion about microarray technology in two short paragraphs at the end.

In general, though, news report B does not report on the particular research that was described in *Nature*. Again, there are vague conclusions like "Together the two studies reveal for the first time the intimate role numerous genes play in determining which malignant cells migrate." What "intimate role" are they talking about? How do the genes identified affect the cell? Also, since the genetic basis of cancer is fairly well-accepted, it is

not likely that the role of genes in metastasis is being revealed "for the first time." As before, there are some important links missing, for instance the connection between the technology and its potential applications ("Because the technique allows scientists to know which genes are turned on and off, it holds the promise of creating customized treatments for patients"). The connection between genes and treatments is not made clear; there is a much larger gap between knowing about the genes and creating customized treatments than the article intimates.

Instead of being a report of cutting edge research, then, the piece overall reads like a lesson on metastasis. The report focuses on what is *already* known instead of what is *becoming* known. Shifts in the focus or the "angle" of a story are, of course, permissible, given the shifts in audience. However, a shift should not be at the expense of conveying the impact of the scientific discovery being reported. Neither of these newspaper reports draws a distinction between established knowledge and new research, a point that the Policy Perspective writers in *Public Understanding of Science* deemed important (Field and Powell, 2001).

3. Discussion

Translation and its limitations

The role of the science reporter is to explain research clearly so that the reader can understand the science and the issues involved and act accordingly. Conveying specialized knowledge to a reader in plain language is vital, and the "ability to organize knowledge so that the world becomes intelligible is not a trivial feat" (Bolles, 1997: xvii). However, attempting to move knowledge from the world of scientists into the public sphere presents real challenges to reporters and to newspapers that have to contend with limitations on space and reader interest.

Reporters have, for the most part, become adept at finding ways to explain basic knowledge, and eliciting these sorts of explanations from scientists. Both news articles above feature a variety of metaphors that help the reader visualize the phenomenon (metastasis) being described.[1]

When we compare the original research paper to the news reports, considering the different audiences to which each type of piece is appealing, it is not surprising that the different pieces of writing employ different language. What is surprising is that the distinction is not so much in the language of the piece, i.e., in the use of everyday terms as opposed to scientific jargon. Rather, there is, in fact, a significant difference in *what* is said rather than in *how* it is said. Recalling the premise of science reporting being in large part translation, this change in content bears further investigation.

The necessity of the public being aware of the knowledge being generated by science and the challenges of communicating pieces of emerging knowledge in science are quite evident; however, science communicators and analysts have further noted how, in order for it to be useful, this knowledge must be presented in context. Dorothy Nelkin, in *Selling Science: How the Press Covers Science and Technology* (1995), frequently comments on the media's failure to communicate or question the nature of scientific processes, even when these processes are central to the issue, for instance in cases of publication fraud and major industrial accidents.

In general, it seems that the findings of the data presented in the news pieces analyzed here are similar to those identified by Rogers (1999) and Rowan (1999). As in Rogers' study, these news reports lack information and a suitable level of detail, assuming background knowledge that the reader is not likely to have, or, in this case, not supplying the detail that will enable readers to make connections. Again, there is lack of the context that would help readers get a sense of the importance of the findings, and the way the stories are structured contributes to the slightly disjointed effect. Importantly, while the reporters do provide a certain context and frame of reference, i.e., in the science lesson about metastasis, it is the scientific context, the situating of the findings within the research effort and the current or growing body of knowledge, that is lacking. Both forms or levels of context—the general "how this applies to you" and the specific "what scientists think of this"—are necessary if the reader is to really understand the work.

Holding these reports up to the list of Rowan's suggestions of what journalists should seek to learn, and presumably, convey, it is obvious that her ideals are not part of common practice. The reports provide little evidence in support of the findings, and "what parts of the puzzle remain unsolved" are alluded to only in a very general way. On a more encouraging note, what impressed scientists about the findings is reported, and indeed, emphasized. Yet there is little other direct contextual information provided—for instance "what has to happen before the finding is viewed as established knowledge," or "what people can do to learn more" (Rowan, 1999: 206).

To improve scientific understanding by the public, reporting must thus encompass translation in language and in idiom, replacing scientific jargon with plain language and presenting information in its scientific context, where context may mean information about the methodology, history, or sociological environment of the research. The knowledge of discoveries through scientific research will not be as useful or comprehensible if presented without an explanation of the processes through which this knowledge has been gained. Reports need to "help readers weigh conflicting claims" (Nelkin, 1995: 57) and "teach them how to evaluate the evidence" (Rowan, 1999: 206).

The survey of science reporting presented here indicates that the problems identified by Rogers (1999) and Pellechia (1997), and the suggestions of Rowan (1999), are not widely practised. Much like it makes more sense to translate the French *il fait froid* to the English "it is cold," rather than to a literal translation such as "it makes cold," so the translation of science for the public must be informed by an understanding of the "idiomatic" use of scientific language. In other words, research findings cannot be taken as specialized, isolated facts; these findings must be understood in terms of research methods and research efforts. Only in this way does the translation make sense.

We thus propose a model in which the science reporter has three roles: to be an "intermediary," a "watchdog," and a "tool-giver." The first two roles have longstanding acceptance in journalism; the third has had perhaps just tacit acknowledgment, and is the one we would like to add to what is already a remarkable job detail.

First and most important, the reporter naturally has to be an intermediary. The job of the intermediary is what has traditionally been thought of as "translation." Reporters of science explain specialized fields in language a lay public can understand. The early science journalists certainly saw their task in these terms—"True descendants of Prometheus, science writers take the fire from the scientific Olympus, the laboratories and the universities, and bring it down to the people," said a legendary science writer (William Laurence, quoted in Nelkin, 1995: 83). With the increasing specialization and complexity of science, and the increasing competitiveness and design savvy that characterize the media, current reporters have much to handle in trying to be translators in the traditional sense. But

this intermediary role is important, because it is the foundation on which the other roles are built.

The "watchdog" role is also important, as it is in general journalism. Over the past few decades, science journalists have by turns seen themselves as advocates and as critics of science. If the advocate of science is the Promethean, the science critic is the watchdog. In reporting science, the "watchdog" element—the discussion of social and ethical implications of the work, the interest in the wider picture, the crystal-ball gazing—is important not only to generate interest; at its best, it can create awareness of and stimulate thinking about issues that are of public concern. Scientists are wary of the media's tendency towards hyperbole; however, the topics raised are often legitimate.

Finally, we suggest that a third role of the science journalist is to be a "tool-giver." The goal is to give readers the tools with which to think and evaluate the evidence and the issues for themselves. Providing a good explanation of the science and raising questions about the long-term significance of the work are two components of this. The other component is giving direct context; for instance, the current body of knowledge in the subject and the state and direction of research in the field. This context provides a link between the findings and their significance, between current knowledge and future applications. In order for readers to be able to evaluate the science and decide "just how important it [is] in the larger scheme of things" (Nelkin, 1995: 83), they need to be able to frame it in the context of what science knows (the current body of knowledge and the direction of research efforts), how science works (the significance of methods), and how science *really* works (the socioeconomic elements of research practice) (Field and Powell, 2001). Otherwise, the information is interesting but difficult to relate to a current situation or a long-term application. The "tool-giver" role thus rounds out the "intermediary" and "watchdog" roles, to give a more complete model of the "translation" of science for the public, and supports Durant's ideals for better public understanding of science. In addition, scientists, educators, and citizens must also play a role in scientific literacy. Scientists must learn to communicate without jargon, educators must help make science more accessible to non-scientists, and the public must make an effort to stay informed about science.

4. Conclusion

The task of translating science for the public is not an easy one; there are many challenges and constraints that hinder the journalistic contribution to scientific literacy in the public sphere. In newspapers, the most widespread form of written communication with the public, there is a need to re-evaluate the focus and re-imagine the form of science reports.

The job of scientific reporters is made more difficult by the lack of scientific literacy of their readers. Without a basic knowledge of scientific methods and vocabulary, reporters are, by necessity, constrained to report only in the most basic and simple language. The press often tries to provide definitive answers for an inquiring, or sometimes non-inquiring, public. Because of the concerns and constraints of their profession, journalists work in a world of simple and superlative statements. The scientific world, however, moves with caution and incremental knowledge. A good translation must be consistent with its source as well as cater to its audience. Reporters have the challenging role of being a good "intermediary," being a "watchdog," and giving the public the "tools" with which to use the information they present. We look forward to continuing advances in how research is

reported, as journalists, readers, and scientists adapt to the pace and progress of millennial science.

Note

1 For example, from the *USA Today* piece: "tumor cells must burst free from their moorings, move to distant locations and become established there." Descriptions from the *Newsday* piece: "cancer cells . . . break away from their original tumor and seed new tumors in distant sites"; "wanderlust"; "cancer cells stray"; "evade the body's warrior cells"; "the bloodstream is turbulent, it's a raging river"; "properties of adhesion, the biological glue that keeps all cells in their places"; "renegade cancer cell"; "rogue cancer cell." The last two descriptions are reminiscent of Whitehead Center scientist Robert Weinberg's book explaining cancer, entitled *One Renegade Cell*, though in that case, the renegade cell can be one that divides uncontrolled to form a tumor, rather than necessarily a cell involved in metastasis.

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