8 PHYSICISTS READING PHYSICS

SCHEMA-LADEN PURPOSES AND PURPOSE-LADEN SCHEMA

Just as a scientist writes as part of an active life within a research community, the scientist reads as part of the continuing activity of research. If texts are not—cannot be—produced by the simple transcription of natural fact, no more can they be read as a direct apprehension of contextless meaning. Readers make their readings, each for their own purposes and by their own lights.

Yet, although each reading is a personally constructed event, the individual reading is embedded in communally regularized forms, institutions, practices, and goals. The reading is part of the historical realization of a communal project. In the same way that each scientific article, although a totally new document, bears significant similarities and relations to prior and future texts, each reconstruction of meaning through reading coheres with other readings as well as other structured elements of the scientific endeavor. Twentieth-century physicists read articles in physics within the activity and structure of twentieth-century physics. Their reading is motivated and shaped by their participation in that communal endeavor.

Although reading consumes a substantial part of a research scientist's working life, science studies have not looked very far into exactly what happens when a scientist reads and how this reading is precisely related to scientific activity. Macroscopic surveys have documented the amount of time scientists in different specialties read, what kinds of documents they read, and from which source they identify documents they might read. But in these studies, largely driven by information science interests in improving accessibility to information, the process of reading itself has not been considered problematic. The only substantial research into the processes by which the scientific literature is read has been through examination of citations to articles in subsequent literature. These studies of citation use and transformation (most notably the work of Cozzens and Small) have indicated some of the patterns by

which interpretations and evaluations of read texts become meaning-carrying elements in new writing. These citation studies suggest strongly how intimately reading and writing are tied together in an intertextual system of knowledge creation. Yet these studies still have only looked at the reader after he or she has written a new text. They have not yet looked at the reader reading, or even at the reader in the process of writing, relying on earlier texts.

Literary studies and cognitive psychology have turned more thoroughgoing attention to the problem of constructing meaning from reading. Literary studies, concerned with poetic meaning, have turned from both the intentions of the author and the text itself to the reader's construction of meaning from the fixed set of words of a text. Iser and Eco, for example, have been concerned with how texts guide those constructive processes to varying degrees, whereas others, such as Holland and Bleich, see the construction of meaning as almost wholly guided by the reader, so much so that the text has little role in determining meaning. Extensive annotated bibliographies appear in Tompkins, Suleiman and Crosman, and Holub. At the same time as the meaning of the text is seen to reside within the reader, that meaning is also seen to develop out of a web of relations with other texts. The reader reads not a single text, but an intertext which creates both the traces of language familiar and meaningful for the reader and the presuppositions on which the reading rests. Kristeva first developed the concept of intertextuality; a recent survey appears in Orr.

In cognitive psychology, studies of children learning to read have considered comprehension as a product of a reader's interaction with a text. Readers actively employ their structured background knowledge (or schemata) in order to understand a text (Rumelhart and Orotony; Spiro; Reynolds et al; Steffensen; Bruce). Furthermore, the reader's purpose in reading helps the reader define a reading strategy and select what information to glean from the text (McConkie, Rayner, and Wilson; Reynolds and Anderson). Differences in schema or purpose that the reader brings affect both the process of comprehension and the meaning constructed from the text. Johnston reviews much of this work.

In making the meaning of a text a socially active phenomenon, these constructivist approaches to reading problematize scientific knowledge by calling into question the concept of a fixed text. On the other hand, the study of reading processes can also illuminate how reading is placed against experience and how shared meanings form. Meaning construction has empirical and sociological elements as well as psychological. The reader is not an isolated mind, devoid of experience and community.

In this chapter I report on the reading processes of seven research physicists, based on data gathered from a series of interviews and observations. Throughout the interviews and observations, two themes from contemporary reading research proved indispensable in understanding how these professionals manage the literature in their fields: the reader's purpose and schema of background knowledge. The researcher's own need to carry on research and his or her own understanding of the field clearly shape the reading process and the meaning carried away from the professional literature. Moreover, purpose and schema are intertwined, so that the reader's schema incorporates active purpose and purpose is framed by the schema. In this dynamic interplay any article has the potential for reshaping the reader's schema and purpose.

Since the purposes for reading derive from the reader's own active research program and the schema are constructed around that program, interpretation and evaluation of read texts are intimately bound up with the empirical experiences and emerging empirical projects of both the individual and the discipline. Scientific reading is drawn into that same structured web of doing and formulating that constrains and occasions scientific writing. Texts are read against a continuing disciplinary activity in the world and judgments about how that activity might be most successfully continued. With readers already in motion, mentally and physically, texts are drawn into constant and consequential contact with the natural world.

The Interviews

The seven physicists I interviewed and observed represent a variety of specialties: three (T1, T2, and T3) are small particle theorists; two (BP1 and BP2) are experimentalists in biophysics; and two (RS1 and RS2) work with applied theory in the area of remote sensing. Five are from the same middle-sized private technological university (RS1, BP1, T1, T2, T3). RS2 is from a nontechnological branch of a large public university. The last, BP2, is the head of a lab at a major research university. He is the only one who regularly works as part of a consistent lab team. The rest either work individually or collaborate intermittently.

Single interviews with each lasted from 90 to 120 minutes (except for T3 whom I interviewed for about 250 minutes over three sessions) and were tape recorded. Each interview included a discussion of the subject's reading practices; with four subjects I was able to observe reading

activities—library search for materials, scanning tables of contents, reading of articles—and then discuss what happened. The three interview sessions with T3 consisted of (1) a general interview; (2) an observation and focused interview of a library search for materials and quick first reading of those materials in the library; and (3) observations and focused interviews on careful readings of two articles.

With all the subjects who were observed and interviewed, I noticed no obvious differences between their accounts of their practices and the observed practices. They seem to do what they say they do. The observed activity, however, did lead to a more detailed discussion in the consequent focused interview.

Purposeful Choices

All through the reading process the physicists interviewed carefully select what they pay attention to and retain based on the needs of their own research. The continuation of their own research projects forms the purpose for the reading and, thus, determines what they want to get from reading.

The range of these physicists' serious reading is defined by what they feel necessary for current or anticipated work. If their work is on well-known puzzles with a substantial literature, they read mostly work similar to their own. If they perceive their current work touching on many fields, they search more widely for relevant work. Furthermore, they all accept the distinction between core reading close to their own work and peripheral reading. Finally, some read for prospective work: to tutor themselves, to gather information, or to window shop for potential problems to work on.

In terms of amount of reading, all define their "must" reading by the amount available and relevant to their issues, whether the amount is large (BP2) or small (RS2). Where time pressure interferes, it affects the more peripheral reading, which gets a more cursory scan.

In order to find the articles necessary for the continuation of their work, almost all these physicists periodically scan the tables of contents of selected journals—whether through *Current Contents* or in the actual journals. They sometimes supplement these scans by computer searches, reviews of the literature, abstract publications, and the *Science Citation Index*.

Schema for Making Choices

In making these early choices of what articles to read, each reader calls on personally organized knowledge. This schema extends beyond textbook knowledge of accepted facts and theories to include dynamic knowledge about the discipline's current practices and projections of its future development. The schema even includes judgments about the work of colleagues.

In selecting the range of reading the physicists must, of course, have a sense of the various fields of current work. Moreover, in deciding the urgency of reading the physicists must rely on an image of how rapidly work moves in their fields. All the pure theoreticians and experimental biophysicists go to the library at least once a week to search the tables of contents of newly arrived journals because they perceive their fields as moving rapidly and they must keep current to do adequate work. Both physicists in remote sensing, however, choose less timely methods of search—one using *Current Contents* and the other using abstract indexes. When questioned about the slowness of their search techniques, both said that their field did not move fast enough for that to matter.

The scanning processes of these physicists give evidence about how deeply these schema are impressed in the subconscious. The subjects scan so rapidly over tables of contents that they cannot give conscious thought to each title. Rather, certain words seem to trigger the attention and make the scanner question a particular title more actively. Indeed, both BP1 and T3 described how certain words seem to pop out of the page in some form of rapid unconscious processing. When I asked the subjects about particular titles they chose to look at further, they always attributed their interest to particular words.

These words are of three kinds, indicating domains of organized knowledge within which the word is immediately and unconsciously placed, then give value:

Names of objects or phenomena. These are the same as or closely related to objects or phenomena being studied by the researcher. Typically T3 reported an interest in an article by the term "atom–diatom collisions" and in another by "spin polarized hydrogen" because in each case that was just the thing with which he was working. BP2 reported that he had "quite a large number of such names. . . . I have a fairly organized view of this field, so I immediately categorize these nouns . . . into a context and make a judgment as to their value."

Names of approaches or techniques. These are not objects themselves, but ways of knowing those objects. RS2 in searching articles and indexes always looks for "remote sensing."

Names of individuals or research groups. All interviewees expressed awareness of who was doing good work in their field, with the three theoreticians being certain about comprehensive knowledge of all the significant actors in the field. Each of the scanners indicated that they were frequently attracted to an article by the name or research group of an author, even if nothing in the article title attracted them.

The importance of knowledge of the important actors in the field is furthered by the role of preprints and recommendations in determining reading. All the interviewees mentioned that many of the most important articles came through the mail as either preprints or reprints, and they paid at least some attention to all articles that arrived in this way. On a few occasions, as the subjects scanned journals, they commented that they would read a particular article, except that they had already seen it in preprint. And most of the interviewees mentioned recommendations by colleagues as an important source of articles.

Complex Choices: Complex Schema

The way that kinds of knowledge fit together in article selection decisions reveal the complexity of the reader's overall schema. Once the scanner's attention has been grabbed by a single term, he or she then will look at the other words in the title. In the observations I made, only about one quarter of the titles that triggered attention on the basis of a single term were actually looked at. All others were deleted on the basis of the other information of the title and author.

In the simplest deletion cases, further words in the title defined the phenomenon or the technique more precisely so as to place the article outside of the researcher's interest. For example, RS2 would regularly eliminate titles signaled by the keyword "remote sensing" if the title indicated any wavelength region other than infrared, for not only was the specific information different, the problems of measurement were also different in the other wavelength regions.

Similar, but more interesting, were the cases in which the technique that triggered attention was, on closer inspection, discovered to be applied to a different phenomenon. T3, for example, was attracted to the acronym DWIA (meaning Distorted Wave Impulse Approximation) in a title because he had used that method before and had referred to the acronym in his published work. He eliminated the article, however, when he saw that the research site was a molecule much more complex than the one with which he was working; he anticipated that the calculations would look entirely different. With respect to a similar example,

he commented that the elaboration of a technique would be totally different in a new domain.

Conversely, the phenomenon may be right and trigger attention, but then a glance at the technique term of the title will eliminate the article because the reader feels that the method or technique cited is either unpromising or unlikely to produce calculations or results interesting to the researcher. T2 does not find work produced by the shell model currently interesting; although he was attracted by a title mentioning a phenomenon directly related to his problem of nuclear shape, he bypassed the article because it used this model.

The intersection between names of authors and the substance of their titles allowed readers to predict how a piece of work might go and thus how useful it might be. T2, for example, although attracted by the substantive terms of a title, passed over an article on the basis of the authors because he felt that they were only redoing what they had been doing for the past five years, only calculating higher-order terms. He called this work "too messy . . . extremely long and complicated. . . . I am sure the calculations are right, but it is the wrong approach." On the other hand, he also expressed some interest in an article, despite a title indicating work totally outside his area, because he knew the author to be doing interesting work that might be of importance for the whole field.

When the title and author provide inadequate, ambiguous, or misleading information the reader will turn to the abstract to decide whether the article is worth reading. Because the abstract usually contains more information, it allows a more precise placement of the article within the schema, and the process of placement reveals the complex multidimensionality of the schema. In one particularly revealing example, T2 was first attracted to the coauthored article both by the name of one author and by the title of the article. However, as he read the abstract he became confused, saying this "went beyond the previous work." Then he seemed unsure about what the abstract was saying. Finally, he realized that the article was based on the work of the research group of the other coauthor. The meaning of the abstract came clearly into focus, but as T2 did not find the current work of the other research group nearly so interesting, he dropped the article at this point. Thus, the same topic, in part from a respected author, because it came from a different research program, suddenly became judged less interesting or less consequential to the reader's work. This example bespeaks the reader's highly articulated and purposeful sense of the work going on in the field.

Purpose-Laden Schema

Through these examples we can see that in deciding whether to look further into an article, the reader is actually placing the article within his or her personal map or schema of the field. As in Steinberg's famous drawing of a New Yorker's map of the world, the items are given various importance or size based on the observer's perspective—in this case the reader's own work. Some items loom large and must be investigated in detail, whereas others seem to fall off the end of the known personal universe. The map is so well developed that just from the clues of the title, author, and perhaps the abstract, the reader can make strong predictions about what an article in a significant area in the map is likely to contain. T2 was able to predict correctly that an article would use techniques twenty-five years old in familiar expansions, because new techniques under the same name had not yet diffused to the geographic locale of the author and the applications indicated in the article title.

Unlike Steinberg's terrain of fixed landmarks (analogous to a codified picture of nature), however, the working physicist's map applied to his or her reading is a dynamic exploratory one built on the problems on which the field is working, the way the problems are being worked, and which individuals are working on what. The map embodies the physicist's personal perceptions of the forward motion of the discipline of which the researcher considers himself or herself a part. The personal map changes to reflect changing events—new problems being opened up, new actors appearing on the scene, and old problems and actors vanishing. A recent workshop at their university, for example, introduced T2 and T3 to the work of the workshop leader and, consequently, both picked up an article of his in a current journal.

This map, moreover, is seen through the perspective of the reader's own set of problems and estimate of the best ways to solve these problems, so that the map changes as the reader's own problems and guesses about the best approach or technique change. BP2, for example, was once interested in an approach to his subject through the study of divalent cations, but experiments in his lab as well as the inconclusiveness of the large number of articles with this approach convinced him that this was a dead end. Now he does not even look at an article with "divalent cations" in its title.

Purpose-Laden Schema in Understanding the Article

This doubly dynamic schema (a vision of a field in the process of trying to solve problems as seen through the individual's own research interests) provides the framework against which the reader comes to understand an article. The reader will process information that has significance for the existing schema and will view that information from the perspective of the schema. Thus, the way one reads is a strategic consequence of what one is trying to accomplish. How to read turns out to be as fundamental a decision as what to read.

The majority of interviewees read the larger part of articles selectively, seeking what they consider the news—that is, what will fill out or modify their schema or picture of subject and field. But what the news is depends on individual interests and purposes. Theoreticians, for example, may go right to the results of experimental articles to see what kind of data is obtained and must be accounted for by their theory; they are likely to skip over methodological sections as uninteresting and theoretical sections as familiar. Even problem formulations and conclusions may not contain much that is helpful to them.

In work very close to the reader's own, the reader often skips past the largest part of the article as thoroughly familiar, only to stop at the new equation or technique or trick. BP2 reports that a main activity of his reading is to notice things that don't fit his expectations. "There are some things that go against what you expect, that trigger the attention: 'Is this right?' If so, then something is missing [from our knowledge]. . . . From our theoretical knowledge and our basic understanding we know a great deal how things are supposed to go. . . . Some other things are a little surprising. . . . Somebody should check that."

Frequently the interviewees read backwards, or jump back and forth, depending on their interests or as one section raises questions about earlier ones. They generally do not read articles sequentially. In quite a number of cases, both reported and observed, the readers looked at the introduction and conclusions, perhaps scanning figures, to get a general idea of what the writer was trying to do. Then they simply filed the article for possible later reference. They only gave the article more careful reading at that time if the article seemed important to their work.

Even when articles are read sequentially, to reconstruct the author's argument, frequently the detailed mathematics are skipped over, with only a look at the kind of equations that result. The derivations are simply assumed to be correct.

Purposeless Information and Hazy Schema: Confusions and Black Boxes

Because readers gain the meaning of articles through their schema, parts of articles that do not readily fit against the comprehension schema create difficulties. Some parts of articles appear irrelevant and thus fall off the edge of the map; others are terra incognita—part of the relevant world but not sufficiently well-known. Some are not drawn clearly enough to clarify one's existing picture; and some do not fit well against existing schema and thus seem confusing in meaning. How readers deal with these lapses in comprehension depends on their perception of how potentially significant the passage is.

Where articles contain unfamiliar or difficult material, the reader weighs the cost of working through the difficulty against the potential gain. Such situations occur when the article requires technical knowledge outside the range of the reader or contains detailed calculations or derivations. All of the interviewees at times have to look up background material in reference works and textbooks. On the other hand, RS1 and RS2 both find their field so interdisciplinary that they inevitably must live with wide ranges of relevant ignorance. T1, T3, BP2, and RS2 frequently skip across complex mathematics, only identifying the techniques, the general gist of the derivation, or the results, unless they feel they have to know the derivation for their own work. A significant subcategory of this is the computer program used to generate results. Only in exceptionally significant situations will the reader request a printout of the program for detailed analysis.

Sometimes the articles are so poorly written that the reader cannot follow the argument or its meaning. Here, one must calculate not only the effort, but the possibility of adequate reconstruction. Enigmatic conciseness or disorderly presentation of the key steps of the derivation lead to troubling obscurity for all three theoreticians. Furthermore, bad writing signals a poorly framed problem, inadequately defined assumptions, fuzziness of method, or unclear results. T3 reports that such difficulties lead to "a false sense of the connection between that work and yours." BP1 comments that when he finds a model fuzzy, it "may be because I don't understand the model or the author does not understand the model."

Another form of haziness occurs when, despite clear presentation, the data are not clearly significant. This is of particular concern to BP2, who works in an area with many experimental results being published for many of which, BP2 feels, the problem addressed is inadequately defined or the techniques are not appropriate.

When articles project representations of nature that do not correspond with either accepted data or related accepted theory, the reader can have trouble figuring out what the author has in mind. Coherence with contextual knowledge is important in enabling the reader to interpret a set of claims. BP1 reported being baffled by an article and bringing it to an expert in the area who said the article "was just wrong. You know, wrong. It should not have been published." Meaning seems to come from being able to fit the article in with what you know.

If the new message cannot be meaningfully associated with what the reader knows, the reader finds it difficult to obtain a meaning from it. Moreover, he or she has difficulty reading it like a fiction—the presentation of a hypothetical world. In reading, as in the rest of their work, these physicists are guided by the purpose of building up a picture of the actual world. If a statement does not fit in with the endeavor, it does not convey a significant meaning.

At times articles may be only temporarily confusing, for upon consideration the reader readjusts the schema to incorporate the puzzling material. After reading a particularly profound article, RS2 thought about it for a number of days before she felt she understood it fully in all its consequences. BP1 reports a more subconscious version of the process of schema reshaping or refinement: "I may say, 'gee, I don't understand it,' and put it in a drawer for a week or two . . . then I look at it again and the penny drops." The temporarily confusing statement requires one to think differently, and is confusing only as long as it takes to change one's way of thinking. The statement must be of such apparent promise and importance that the reader will reshape the schema for it.

Opening Up Black Boxes

Two reasons motivate the interviewed physicists to work through comprehension difficulties: either to add to their background knowledge or to mobilize aspects of the article in their immediate work. Each reason leads to a different reading strategy.

In filling in one's ignorance, one is likely to read trustingly and uncritically. One adds new information to one's schema, familiarizing oneself with new concepts and techniques. RS1 describes his method of using the article as a tutorial: "I will read it in various stages. After I have read it once I will go through it again. I will look at some of the basic crucial references. . . . Then, I will try to verify some of the equations . . . and chances will be I won't know where they got them. . . . In order to verify the equations I would have to spend some time . . . look on

some other papers, on the other references, occasionally they may come from a textbook. . . . Then I would consider it as part of the background I would understand."

On the other hand, a second reading in anticipation of immediately using the results is likely to be more critical, concerned with placing the article in and against one's existing schema, deciding carefully just what role the new material ought to take. Because one will be building one's own actions and statements on the material, one considers the argument, methods, evidence, and claims cautiously. Deciding to integrate another's work into one's own is the core of the communal endeavor of science. But it is a wary communal endeavor.

The following extended example reveals how detailed reading involves detailed schema matching and judgments as to the value of integrating the material more deeply into one's schema. T3 read twice through an article about a mathematical technique that he was interested in applying in his own work. After selecting the title on the basis of the name of the technique, he immediately "knew roughly what the article was trying to do." The issue now was whether the technique was worth the effort to acquire and employ.

On the first quick five-minute reading, T3 skipped through the article, looking at the equations and a results table to note the difficulty of the equations and the accuracy of the results in comparison to experimental figures. At this point he noted that the method would get accurate results, but only after a fifteen-term expansion. He would have been happier with accuracy after a five-term calculation, but he still considered this method worth a further look, particularly after skimming the conclusion that said that the method was "practical and numerically stable." As T3 knew the authors and respected their judgment, he gave the article another, more careful reading from the beginning, for an additional half hour.

In this slower reading he followed the mathematical reasoning more closely, although he still did not derive or work through all the equations. He noted the expansions of the equations used, but could not find any reason for the choice of these particular expansions. Also, he noticed many subproblems involved in completing the expansions. The error/accuracy estimates and the method of generating certain functions required more computer capability than he had available. As he read two textbook-type examples, he felt the desire for a more complex example. The method began to seem less attractive to him, requiring great efforts to solve insufficiently complex problems. He consequently reinterpreted the author's judgment of "practical and numerically stable" as a rather lukewarm evaluation. At this point he decided not to

work through the equations, which would have constituted his third reading if he had found the method more attractive. Through the comparison between the article's proposed method and methods already familiar to T3, the article, which at first seemed a potentially major contribution to T3's schema, shrank to inconsequentiality.

Evaluating Articles: Criteria for Modifying Schema

Detailed reading motivated by anticipation of using the results, as we have just seen, merges into evaluation. For fitting new material into an already highly articulated schema is a judgment-laden process, affecting each reader's future work. The accumulation of such individual evaluations of reading influences the course of the whole community's knowledge and work.

All articles in the process of comprehension undergo evaluations of usefulness and importance. The article that remains unread, unused, and uncited suffers a harsh judgment. But even the articles that are read undergo evaluations of apparent importance. The general criterion reported for importance is the amount of news contained in the reading—that is, how significantly the article adds to or shakes up the current schema of what is known and how the field should go about knowing more. This criterion cannot be separated from the individual researcher's basic purpose in reading—finding out what one needs to know to pursue one's work. BP1 finds that an important paper "redefines an area . . . gives you hard information as to where you should be restricting your search." All interviewees associated news with future action as well as a current picture of nature.

Although all articles go through at least an implicit judgment of importance, only some articles undergo significant immediate judgments of their truth or quality. Most articles are considered reliable, on the face, because most of the interviewees read most articles for self-instruction or information in areas beyond their intimate knowledge. Only where prior knowledge is highly focused and articulated is the reading likely to conflict in substantial ways with the reader's schema. As BP1 commented of one article, "From then on, I am not competent to judge whether he is right, so I will be learning." Experimentalists generally do not question theoretical articles, and theorists generally do not question experimental papers.

Only BP2, with a comprehensive field-wide schema, tends to be criti-

cal of most of his reading. Whereas, for example, other interviewees report using a pencil and paper while they are reading for self-instructive functions (working through derivations, making notes and outlines), BP2 always reads with a pencil in his hand, making critical evaluative comments: "I scribble something awful."

The judgments, when made, often reflect a vision of how such works should go, rather than a sense of the substance of the statements. That is, readers compare the articles with the parts of their schemata that suggest how work should proceed rather than state what results should be. Internal evidence and stylistic features give the readers clues to the article's reliability. BP1 relies on the wording as an indicator: "The way a paper is phrased tells you if he is of this epoch and knows what he is talking about. Often you will get papers whose wording is wrong. . . . Sometimes it is really so strange you know something is odd." Both BP1 and BP2 are positively impressed when the author admits experimental or methodological difficulties, particularly if they are aware of the difficulties from their own experience. BP1 said, "only a careful guy does these things." BP2 commented: "Some . . . experimental sections are crisply clear and little goodies are buried in it, like 'it turns out that one cannot do it this way because' . . . or 'there is a little artifact in these results' and the guy spells out how he avoided it. Very good. This kind of paper you can believe because the guy clearly knows what he is doing."

The clarity of the model being presented also concerns the readers. T2, for example, finds an article suspect if the assumptions, methods, or results are not laid out clearly, for such fuzziness of presentation may indicate fuzziness in the work.

To evaluate the substance of statements, the interviewees generally rely on their own methodological experiences. The experimentalists interviewed examine experimental technique to see if it accords with their own experience of how such experiments should be run. BP1 asks, "What techniques, what kinds of techniques did they use? Did they follow the necessary protocols?" The theorists who create simplified models of complex systems question the simplifying assumptions of articles being read based on their own experiences in working with various assumptions. T2 calls the evaluation of assumptions the most critical evaluation he makes, for given the article's assumptions, the consequent calculations are rarely wrong. The whole problem of his field is to choose the right simplifying assumptions.

The existing body of published experimental results also plays an important role in the evaluation of both theoretical and experimental articles. In evaluating theoretical results, T1, T2, and T3 all look to see how well the calculated values compare with experimental results. This

is then balanced against the simplicity or cumbersomeness of the method of calculation. When looking at experimental results, the experimentalists BP1 and BP2 note whether the results fit their expectations. BP1 comments: "Are the effects that should be there, there, and the effects that shouldn't be there, not there?"

In some cases, for some purposes, an article may not accord with the reader's perception of the problems, the significance of previous literature, or the meaning of the current results, but the reader will ignore those differences to take from the paper what appears novel or important. This selective evaluation is strong evidence for the priority of one's individual schema in evaluating results over an absolute, textually based standard. That is, arguments are generally evaluated not with respect to the correctness of the entire argument, but to how the reader can assimilate pieces into ongoing work.

Evaluation Changes over Time: Changing Schema and Changing Field Purposes

The judgments made upon reading articles are not necessarily final. BP1, for example, notes, "Sometimes I miss things. . . . I think things are not particularly interesting, and then I kick myself later for having missed it." Later work may show an error in a piece of work, but more often evaluations change because the field in some way leaves the work behind (or in a few cases, catches up): either new methods and experiments prove to be stronger or the general thinking of the field has changed so as to alter the schema against which the article is placed. In BP1's words: "My model of the universe would change . . . along with a majority of the people in the field. . . . There is sort of a drift."

T1 shows a similar awareness of the evolutionary nature of the field and how one's changing schema is tied to that evolution. When he evaluates the quality of the results from a method of approximation, he allows a greater margin of error for the first attempt at a theoretical calculation than he does after a number of people have proposed solutions.

Schema-Laden Purposes

Articles, in their challenge to existing statements, foment new work. Plausible new methods, evidence, claims, and interpretations change the landscape against which the researcher plans and

realizes research purposes. Just as schema embed the purposes of the individual researchers, purposes embed the researcher's schema.

In an immediate way, both experimentalists and theoreticians report doing more work to confirm striking results in their field. RS1 said: "If I am working on the problem, then of course I would do a series of things to verify and test" the novel results. BP2 similarly said he would carry out or assign one of his subordinates in the lab to carry out further experiments to explore and test novel results, as when one of his graduate students showed that some published results were artifacts.

Over the long term the body of claims from the corporate literature that are integrated into the individual's schema will close off certain problems and methods and open up others. A changing picture of nature and the dynamics of investigation, all garnered from reading, will modify research purposes. The researcher acts on what he or she knows, and much of what the researcher knows comes from reading.

Constructing a Literature

Given this evolutionary understanding of their work and their colleagues' work, the interviewees recognize that their thinking and knowledge reflect the joint endeavor of constructing a literature. Their view of nature is directed toward making more statements about nature and their statement-generating actions are based on schema arising from previous statements.

The interviewees express a variety of opinions about their vision of nature, but none claim an unmediated, clear, and certain access to nature. T1 most directly states that he does not believe in such a thing as a truth about nature, but only greater or lesser solidity in the statements we make about nature. T2 and T3 admit having only an impression of the phenomena they theorize about through what is reported in the literature. Although T2 does admire some of the experimentalists he works with who seem to have a concrete feel for the actual phenomena, he has learned never to say "nature is not like that," rather, only "nature could not be that complicated." The experimentalists interviewed, indeed, seem to have more of a feel for concrete nature, but they still find it hard to disentangle nature from the impression created by the literature.

If the literature is then understood, criticized, and evaluated against an image gleaned from the literature rather than against nature itself, we are confronted once again with the epistemological problem of the socially constructed nature of science and scientific knowledge. In this study we find texts being read piecemeal for specific pieces of informa-

tion. We see the information being placed within and against personal frameworks of knowledge. We see individual purposes and uses driving and shaping the reading. We see new statements being accepted based on how well they integrate with existing schema of how work should go. We see much reading accepted noncritically, from lack of experience with the work being discussed.

Evaluations, moreover, seem to be deeply enmeshed with ad hominem judgments. BP1, for example, does not necessarily look too closely at the experimental section of a paper if he knows the colleagues and their work well—he is personally familiar with their experiments. Even personal factors enter into the process of criticism. RS1 notes: "If you are stepping on someone's toes, it may be very difficult." When you step on toes demands of proof are higher. Proof criteria similarly go up when results are startling, as RS1 points out, for then, in a sense, you are stepping on everybody's toes, making them all reevaluate their schema. Thus, even standards for public argument are situational, depending on the degree of competition and conflict.

Furthermore, reading habits and procedures seem affected by psychological and sociological variables. BP2, for example, as head of a laboratory, has wide reading responsibilities and a critical function, but he also reports that ever since childhood he has read broadly and critically. Whether he became a lab head because of these habits or developed these habits as part of his rise and then reinterpreted his childhood to fit his new self-conception, there is role-appropriate behavior.

Within this welter of individual mind and circumstances, various purposes, limited criticism, and evanescent texts, we begin to wonder how such a thing as shared understanding of a field is possible, how ideas gradually become accepted or validated, how consistent criteria are possible, or how a coherent canon of knowledge can develop.

Yet, on another level these findings suggest merely that texts communicate from one mind to another, and each mind is organized and purposeful in its own way. In a social system relying on originality and individuality of judgment, each person will take and judge differently. Where they know more they can question more deeply. Where they have questions they question harder.

Communication is a social process. In the comparison of schema across the printed page some shared understandings are reached. These shared understandings are based on many individuals each being individually satisfied that claims accord with experiences and best judgments about how the world should be conceived and science conducted. Moreover, those whose work is closest to one another most often have to judge one another's work to carry on their own. What emerges from the

conflict and integration of the schema of those closest to the material does, then, represent a consensus to be taken seriously. As BP1 remarks, through phrases such as "the current mythology" and "our faith is," colleagues at conferences recognize agreement even on matters for which there is little solid evidence. All of the interviewees assumed a wide range of shared perceptions with their colleagues except in specified areas of difference or well-known open problems.

The long-term process of scientists building on one another's results, moreover, seems a powerful corrective to the idiosyncracies of individual work and short-term misunderstandings and misevaluations. Although individual experiments and calculations may be plausible or implausible, correctly or incorrectly understood and evaluated, replicated or not replicated, in the long run they must accord with the continuing experience of a range of researchers in order to maintain current acceptance. The statements that will have a continuing life in the literature will be those that readers will consistently integrate into their work.

Within such a social understanding of the construction of a scientific literature even such potentially disillusioning behaviors as the necessity of publicizing one's own work at conferences take on important functions. If one can get other people to see how one's work might bear on theirs, they may use it, develop it, refine it, add significant related results to it. T2 comments on the importance of "salesmanship": "A lot of people in nuclear physics . . . have had great success because of a very interesting model to start with, but also in the sense of having done a good sell. This is very important. People may be able to feed back ideas or information in the model. . . . If they see any kind of connection at all [with their own work] they will become interested in it. . . . The more people working in an area, the more ideas will be generated; some of them will be good ideas. . . . In the long run that will help the reputation of the model." Idea development is a communal development.

The short-term reading processes examined in this article fit into this longer-term emergence of scientific knowledge. Each scientist forms a personal view of the field, yet remains willingly accountable to experimental results and reasonably open to any powerful suggestion that comes along in the literature that might affect a work-directed schema upon which individual plans ride. Within this framework what turns out to be most useful to the most workers in the field over a long period has more than faddish significance. *Usefulness, if it is constantly tested from many angles against an uncooperative nature, is in the long run much more than a pragmatic criterion.*

These working research scientists have an extraordinary commitment

to the literatures of their fields. They work hard to keep up with the literature and are willing to change not just their minds, but their plans and work on the basis of what they read. As a number of commentators have noted, the literature for scientists seems similar to scriptures for fundamental believers of the divine word. Yet the differences are major, for scientific reading does not attempt to return to a primary vision. The constant attempt is to add to the scripture, to move on to a better understanding, a new vision. Old parts of the canon are willingly scrapped, despite the resistance that sometimes attends new findings. Most of all, the literature constantly is being held accountable to an outside measure, whereas scripture is usually held to be hermetically true, no matter what the world tells you. Although each scientist is moved to do his or her own good works through individual conscience and reading of the shared texts, ultimately the individual must bend to the world, for that is where the researcher believes good works are to be found.