How to Write and Publish a Scientific Paper

Ninth Edition

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Preface

> *Criticism and testing are of the essence of our work. This means that science is a fundamentally social activity, which implies that it depends on good communication. In the practice of science, we are aware of this, and that is why it is right for our journals to insist on clarity and intelligibility.*
>
> —Hermann Bondi

The goal of scientific research is publication. Scientists, starting as graduate students or earlier, are measured primarily not by their adeptness in the laboratory, not by their knowledge of scientific subjects, and certainly not by their wit or charm; they are measured and become known (or remain unknown) on the basis of their publications. On a practical level, a scientist typically needs publications to get a job, obtain funding to keep doing research in that job, and get promoted. At some institutions, publications are needed to obtain a doctorate.

A scientific experiment, no matter how spectacular the results, is not completed until the results are published. In fact, the cornerstone of the philosophy of science is based on the fundamental assumption that original research *must* be published; only thus can new knowledge be authenticated and then added to the existing database that we call scientific knowledge.

Unlike those in many other fields, scientists must provide a document showing what they did, why it was done, how it was done (so others can try to repeat it), and what was learned from it. The key word is *reproducibility*. That is what makes science and scientific writing unique.

Thus, the scientist must not only "do" science but also "write" science. Bad writing can (and often does) prevent or delay the publication of good science.

CHAPTER 1

What Is Scientific Writing?

> *State your facts as simply as possible, even boldly. No one wants flowers of eloquence or literary ornaments in a research article.*
>
> —R. B. McKerrow

THE SCOPE OF SCIENTIFIC WRITING

The term *scientific writing* commonly denotes the reporting of original research in journals through scientific papers that follow a standard format. In its broader sense, scientific writing also includes communication about science through other types of journal articles, such as review papers summarizing and integrating previously published research. And in a still broader sense, it includes other types of professional communication by scientists—for example, grant proposals, oral presentations, and poster presentations. Related endeavors include writing about science for the public, sometimes called *science writing*.

THE NEED FOR CLARITY

The key characteristic of scientific writing is clarity. Successful scientific experimentation is the result of a clear mind attacking a clearly stated problem and producing clearly stated conclusions. Ideally, clarity should be a characteristic of any type of communication; however, when something is being said *for the first time,* clarity is essential. Most scientific papers, those published in our primary research journals, are accepted for publication precisely because they contribute *new* knowledge. Hence, we should demand absolute clarity in scientific writing.

RECEIVING THE SIGNALS

Many people have no doubt heard this question: If a tree falls in the forest and there is no one there to hear it fall, does it make a sound? The correct answer is no. Sound is more than pressure waves, and indeed there can be no sound without someone to hear it.

Similarly, scientific communication is a two-way process. Just as a signal of any kind is useless unless it is perceived, a published scientific paper (signal) is useless unless it is both received *and* understood by its intended audience. Thus we can restate the axiom of science as follows: A scientific experiment is not complete until the results have been published *and understood*. A published paper is no more than pressure waves unless it is understood. Too many scientific papers fall silently in the woods.

UNDERSTANDING THE SIGNALS

Scientific writing is the transmission of a clear signal to a recipient. The words of the signal should be as clear, simple, and well ordered as possible. In scientific writing, there is little need for ornamentation. Flowery literary embellishments—metaphors, similes, idiomatic expressions—are very likely to cause confusion and should seldom be used in research papers.

Science is simply too important to be communicated in anything other than words that have a certain meaning. And the meaning should be clear and certain not just to peers of the authors, but also to students just embarking on their careers, to scientists reading outside their own narrow disciplines, and *especially* to those readers (most readers today) whose native language is other than English.

Many kinds of writing are designed for entertainment. Scientific writing has a different purpose: to communicate new scientific findings. Scientific writing should be as clear and simple as possible.

UNDERSTANDING THE CONTEXT

What is clear to a recipient depends both on what is transmitted and how the recipient interprets it. Therefore, communicating clearly requires awareness of what the recipient brings. What is the recipient's background? What is the recipient seeking? How does the recipient expect the writing to be organized?

Clarity in scientific writing requires attentiveness to such questions. As communication professionals advise, know your audience. Also know the conventions, and thus the expectations, for structuring the type of writing that you are doing.

ORGANIZATION AND LANGUAGE IN SCIENTIFIC WRITING

Effective organization is key to communicating clearly and efficiently in science. Such organization includes following the standard format for a scientific paper. It also includes organizing ideas logically within that format.

In addition to organization, the second principal ingredient of a scientific paper should be appropriate language. This book keeps emphasizing proper use of English because many scientists have trouble in this area. All scientists must learn to use the English language with precision. A book (Day and Sakaduski 2011) wholly concerned with English for scientists is available.

If scientifically determined knowledge is at least as important as any other knowledge, it must be communicated effectively, clearly, and in words with a certain meaning. The scientist, to succeed in this endeavor, must therefore be literate. David B. Truman, when he was dean of Columbia College, said it well: "In the complexities of contemporary existence the specialist who is trained but uneducated, technically skilled but culturally incompetent, is a menace."

Given that the ultimate result of scientific research is publication, it is surprising that many scientists neglect the responsibilities involved with this aspect. Scientists will spend months or years of hard work to secure data and then unconcernedly let much of their findings' value be lost because of their lack of interest in the communication process. The same scientists who will overcome tremendous obstacles to carry out a measurement to the fourth decimal place will be in deep slumber while a typographical error changes micrograms to milligrams.

English need not be difficult. In scientific writing, we say, "The best English is that which gives the sense in the fewest short words" (a dictum printed for some years in the *Journal of Bacteriology*'s instructions to authors). Literary devices, such as metaphors, divert attention from substance to style. They should be used rarely in scientific writing.

CHAPTER 2

Historical Perspectives

> *I imagine the early scientists of the Royal Society involved in creating the first journals: If they came forward to 2020, everything in our world would shock and terrify them, but they'd find deep comfort in scientific journals.*
>
> —Michael Eisen

THE EARLY HISTORY

Human beings have been able to communicate for thousands of years. Yet scientific communication as we know it today is relatively new. The first journals were published about 350 years ago, and the *IMRAD* (introduction, methods, results, and discussion) organization of scientific papers has developed within about the past century.

Knowledge, scientific or otherwise, could not be communicated effectively until appropriate mechanisms of communication became available. Prehistoric people could communicate orally, of course, but each new generation started from essentially the same baseline because without written records to refer to, knowledge was lost almost as rapidly as it was found.

Cave paintings and inscriptions carved onto rocks were among the first human attempts to leave records for succeeding generations. In a sense, today we are lucky that our early ancestors chose such media because some of these early "messages" have survived, whereas messages on less-durable materials would have been lost. (Perhaps many have been.) On the other hand, communication via such media was incredibly difficult. Think, for example, of the distributional problems that the U.S. Postal Service would have today if the medium of correspondence were 100-lb (about 45-kg) rocks. It has enough troubles with 1-oz (about 28-g) letters.

The earliest book we know of is a Chaldean account of the Flood. This story was inscribed on a clay tablet in about 4000 BCE, antedating Genesis by some 2,000 years (Tuchman 1980).

A medium of communication that was lightweight and portable was needed. The first successful medium was papyrus (sheets made from the papyrus plant and glued together to form a roll sometimes 20 to 40 ft [6–12 m] long, fastened to a wooden roller), which came into use about 2000 BCE. In 190 BCE, parchment (made from animal skins) came into use. The Greeks assembled large libraries in Ephesus and Pergamum (in what is now Turkey), as well as in Alexandria. According to Plutarch, the library in Pergamum contained 200,000 volumes in 40 BCE (Tuchman 1980).

In 105 CE, the Chinese invented paper, the dominant medium of written communication in modern times—at least until the internet era. However, because there was no effective way of duplicating communications, scholarly knowledge could not be widely disseminated.

Perhaps the greatest single technical invention in the intellectual history of the human race was the printing press. Although movable type was invented in China in about 1100 CE (Tuchman 1980), the Western world gives credit to Johannes Gutenberg, who printed his 42-line-per-page Bible from movable type on a printing press in 1455 CE. Gutenberg's invention was immediately and effectively put to use throughout Europe. By the year 1500, thousands of copies of hundreds of books were printed.

The first scientific journals appeared in 1665, when two journals, the *Journal des Sçavans* in France and the *Philosophical Transactions of the Royal Society of London* in England, began publication. Since then, journals have served as the primary means of communication in the sciences. As of late 2021, there were over 48,000 peer-reviewed scholarly journals, of which over 35,000 were in English. The number of articles published per year appeared to exceed 4 million. The number of journals, the number of articles submitted, and the number of articles published all have been increasing from year to year (STM 2021, pp. 15–17).

THE ELECTRONIC ERA

When many older scientists began their careers, they wrote their papers in pen or pencil and then typed them on a typewriter or had a secretary do so. They or a scientific illustrator drew graphs by hand. They or a scientific photographer took photographs on film. They then carefully packaged several copies of the manuscript and sent them via postal service to a journal. The journal then mailed copies to the referees (peer reviewers) for evaluation, and the referees mailed them back with comments. The editor then mailed a decision letter to the scientists. If the paper was accepted, the scientists made the needed revisions and mailed back a final version of the manuscript. A copy editor edited the paper by hand, and a compositor rekeyboarded the manuscript. Once the paper was typeset, a copy was mailed to the scientists, who checked for typographical errors and mailed back corrections. Before the paper was published, the scientists ordered reprints (freestanding printed copies) of the paper, largely for fellow scientists who lacked access to libraries containing the journal or who lacked access to a photocopier.

Today the process has changed greatly. Word processors, graphics programs, digital photography, and the internet have facilitated the preparation and dissemination of scientific papers. Journals throughout the world have online systems for manuscript submission and peer review. Editors and authors communicate electronically. Manuscript editors edit papers online, and authors receive typeset proofs of their papers electronically for inspection. Journals are available online as well as in print—and sometimes instead of in print; increasingly, accepted papers become available individually online before appearing in journal issues. At some journals, electronic extras, such as appendixes and video clips, supplement online papers. Many journals are openly accessible online, either starting at the time of publication or after a lag period. In addition, readers often can access papers through the authors' websites or through resources at the authors' institutions, or the readers can request electronic reprints. Some of the changes have increased the technical demands on authors, but overall, the changes have hastened and eased the publication process and improved service to readers.

Major trends in recent years have included the increasing use of *preprint servers*—in other words, openly accessible online repositories or archives to which authors post manuscripts before (or sometimes instead of) submitting them to peer-reviewed journals. In physics and related fields, researchers have long posted preprints to the open-access archive now called arXiv, which observed its 30th birthday in 2021 (Celebrating arXiv's 30th Anniversary 2021). More recently, substantial numbers of researchers in biological fields have posted preprints, for example in bioRxiv (Kaiser 2017). The trend accelerated with the advent of COVID-19 and the impetus to share research about it quickly (Kupferschmidt 2020). Related developments have included the advent of *overlay journals,* which are compilations of preprints (and sometimes other online items) that, after peer review, been chosen for inclusion (Alves 2021).

Like circulating drafts to colleagues, posting manuscripts in preprint servers can aid in sharing information, obtaining feedback, and establishing priority. It does not, however, substitute for publication in a peer-reviewed journal or the equivalent. Fellow researchers, members of the public, and the media should be aware that items in preprint servers have not received the scrutiny of formal peer review.

Whereas much regarding the mechanics of publication has changed, much else has stayed the same. Items that persist include the basic structure of a scientific paper, the basic process by which scientific papers are accepted for publication, the basic ethical norms in scientific publication, and the basic features of good scientific prose. In particular, in many fields of science, the IMRAD structure for scientific papers remains dominant.

THE IMRAD STORY

The early journals published papers that we call *descriptive*. Typically, a scientist would report, "First, I saw this, and then I saw that," or "First, I did this, and then I did that." Often the observations were in simple chronological order.

This descriptive style was appropriate for the kind of science then being reported. In fact, this straightforward style of reporting still is sometimes used in "letters" journals, case reports in medicine, geological surveys, and other publications.

By the second half of the nineteenth century, science was beginning to move fast and in increasingly sophisticated ways. Microbiology serves as an example. Especially through the work of Louis Pasteur, who confirmed the germ theory of disease and developed pure-culture methods of studying microorganisms, both science and the reporting of science made great advances.

At this time, methodology became all-important. To quiet his critics, many of whom were fanatic believers in the theory of spontaneous generation, Pasteur found it necessary to describe his experiments in exquisite detail. Because reasonably competent peers could reproduce Pasteur's experiments, the principle of *reproducibility of experiments* became a fundamental tenet of the philosophy of science, and a separate methods section led the way toward the highly structured IMRAD format.

The work of Pasteur was followed, in the early 1900s, by the work of Paul Ehrlich and, in the 1930s, by the work of Gerhard Domagk (sulfa drugs). World War II prompted the development of penicillin (first described by Alexander Fleming in 1929). Streptomycin was reported in 1944, and soon after World War II, the mad but wonderful search for "miracle drugs" produced tetracyclines and dozens of other effective antibiotics.

As these advances were pouring out of medical research laboratories after World War II, it was logical that investment in research would greatly increase. In the United States, this positive inducement to support science was soon (in 1957) joined by a negative factor when the Soviets flew *Sputnik* around the Earth. In the following years, the U.S. government (and others) poured additional billions of dollars into scientific research.

Money produced science, and science produced papers. Mountains of them. The result was powerful pressure on the existing (and the many new) journals. Journal editors, in self-defense if for no other reason, began to demand that manuscripts be concisely written and well organized. Journal space became too precious to be wasted on verbosity or redundancy. The IMRAD format, which had been slowly progressing since the latter part of the nineteenth century, now came into almost universal use in research journals. Some editors espoused IMRAD because they became convinced that it was the simplest and most logical way to communicate research results. Other editors, perhaps not convinced by the simple logic of IMRAD, nonetheless hopped on the bandwagon because the rigidity of IMRAD did indeed save space (and expense) in the journals, and because IMRAD made life easier for editors and referees by indexing the major parts of a manuscript.

The logic of IMRAD can be defined in question form: What question (problem) was studied? The answer is the *introduction*. How was the problem studied? The answer is the *methods*. What were the findings? The answer is the *results*. What do these findings mean? The answer is the *discussion*.

It now seems clear that the simple logic of IMRAD does help the author organize and write the manuscript, and IMRAD provides an easy road map for editors, referees, and ultimately readers to follow in reading the paper.

Although the IMRAD format is widely used, it is not the only format for scientific papers. For example, in some journals, the methods section appears at the end of papers. In some journals, there is a combined results and discussion section. In some, a conclusions section appears at the end. In papers about research in which results of one experiment determine the approach taken in the next, methods sections and results sections can alternate. In some papers, especially in the social sciences, a long literature review section may appear near the beginning of the paper. Thus, although the IMRAD format is often the norm, other possibilities include IRDAM, IMRDRDRD, IMRADC, IMRMRMRD, ILMRAD, and more.

Later in this book, we discuss components of a scientific paper in the order in which they appear in the IMRAD format. However, most of our advice on each component is relevant regardless of the structure used by the journal to which you will submit your paper. Before writing your paper, of course, be sure to determine which structure is appropriate for the journal. To do so, read the journal's instructions to authors and look at papers similar to yours that have appeared in the journal. These actions are parts of approaching a writing project—the subject of the next chapter.

CHAPTER 4

What Is a Scientific Paper?

Without publication, science is dead.

—Gerard Piel

DEFINITION OF A SCIENTIFIC PAPER

A scientific paper is a written and published report describing original research results. That short definition must be qualified, however, by noting that a scientific paper must be written in a certain way, as defined by tradition, editorial practice, scientific ethics, and the interplay of printing and publishing procedures.

To properly define a "scientific paper," we must define the mechanism that creates a scientific paper—namely, valid (that is, primary) publication. Abstracts, theses, conference reports, and many other types of literature are published, but such pieces do not normally meet the test of valid publication. Further, even if a scientific paper meets all the other tests, it is not validly published if it is published in the wrong place. That is, a relatively poor research report, but one that meets the tests, is validly published if accepted and published in the right place (a primary journal or other primary publication); a superbly prepared research report is not validly published if published in the wrong place. Most of the government literature and conference literature, as well as institutional bulletins and other ephemeral publications, do not qualify as primary literature.

Many people have struggled with the definition of primary publication (valid publication), from which is derived the definition of a scientific paper. The Council of Biology Editors (CBE), now the Council of Science Editors

(CSE), arrived at the following definition (Council of Biology Editors 1968, p. 2):

> An acceptable primary scientific publication must be the first disclosure containing sufficient information to enable peers (1) to assess observations, (2) to repeat experiments, and (3) to evaluate intellectual processes; moreover, it must be susceptible to sensory perception, essentially permanent, available to the scientific community without restriction, and available for regular screening by one or more of the major recognized secondary services (e.g., currently, Biological Abstracts, Chemical Abstracts, Index Medicus, Excerpta Medica, Bibliography of Agriculture, etc., in the United States and similar services in other countries).

At first reading, this definition may seem excessively complex, or at least verbose. But those who had a hand in drafting it weighed each word carefully and doubted that an acceptable definition could be provided in appreciably fewer words. Because it is important that students, authors, editors, and all others concerned understand what a scientific paper is and what it is not, it may be helpful to work through this definition to see what it really means.

"An acceptable primary scientific publication" must be "the first disclosure." Certainly, first disclosure of new research data often takes place via oral presentation at a scientific meeting. But the thrust of the CBE statement is that disclosure is more than disgorgement by the author; effective first disclosure is accomplished *only* when the disclosure takes a form that allows the peers of the author (either now or in the future) to fully comprehend and use that which is disclosed.

Thus, sufficient information must be presented so that potential users of the data can (1) assess observations, (2) repeat experiments, and (3) evaluate intellectual processes. (Are the author's conclusions justified by the data?) Then, the disclosure must be "susceptible to sensory perception." This may seem an awkward phrase because in normal practice, it simply means to be published; however, this definition provides for disclosure not just in terms of printed visual materials (printed journals and the no longer widely used media called microfilm and microfiche), but also in nonprint, nonvisual forms. For example, "publication" in the form of audio recordings, if that publication met the other tests provided in the definition, would constitute effective publication. And electronic journals certainly meet the definition of valid publication. What about material posted on a website (for example, preprints)? Views have varied and can depend on the nature of the material posted. For the most current information, consult materials from professional organizations and journals in your field.

Regardless of the form of publication, that form must be essentially permanent. Therefore, scientific papers receive *digital object identifiers (DOIs)*:

(“Types of Scientific Paper” by xkcd [xkcd.com]. Used by permission.)

internet addresses that persist even if, for example, a journal's URL changes or the journal ceases publication. Primary scientific publications also must be made available to the scientific community without restriction (for example, in a journal that is openly accessible online or to which subscriptions are available), and they must be made available to information-retrieval services (for example, Biological Abstracts, Chemical Abstracts, and MEDLINE). Thus, publications such as newsletters, corporate publications, and controlled-circulation journals, many of which are of value for their news or other features, generally cannot serve as repositories for scientific knowledge.

To restate the CBE definition in simpler but not more accurate terms, primary publication is (1) the first publication of original research results, (2) in a form whereby peers of the author can repeat the experiments and test the conclusions, and (3) in a journal or other source document readily available within the scientific community. To understand this definition, however, we must add an important caveat. The part of the definition that refers to "peers of the author" is accepted as meaning prepublication peer review. Thus, by definition, scientific papers are published in peer-reviewed publications.

This question of definition has been belabored here for two reasons. First, the entire community of science long labored with an inefficient, costly system of scientific communication precisely because it (that is, authors, editors, and publishers) has been unable or unwilling to define primary publication. As a result, much of the literature has been buried in meeting abstracts, obscure conference reports, government documents, or books or journals of minuscule circulation. Other papers, in the same or slightly altered form, have been published more than once; occasionally, this is due to the lack of definition as to which conference reports, books, and compilations are (or should be) primary publications and which are not. Redundancy and confusion result.

Second, a scientific paper is, by definition, a particular kind of document containing specific kinds of information, typically in a prescribed order. If the graduate student or the budding scientist (and even some scientists who have already published many papers) can fully grasp the significance of this definition, the writing task might be a great deal easier. Confusion results from an amorphous task. The easy task is the one in which you know exactly what must be done and in exactly what order it must be done.

ORGANIZATION OF A SCIENTIFIC PAPER

A scientific paper is organized to meet the needs of valid publication. It is, or should be, highly stylized, with distinctive and clearly evident component parts. The most common labeling of the component parts, in the basic sciences, is introduction, methods, results, and discussion (hence the acronym

IMRAD). Actually, the heading "Materials and Methods" may be more common than the simpler "Methods," but the latter form was used in the acronym.

Some of us have taught and recommended the IMRAD approach for many years. The tendency toward uniformity has increased since the IMRAD system was prescribed as a standard by the American National Standards Institute, first in 1972 and again in 1979 (American National Standards Institute 1979a). Some journals use a variation of IMRAD in which the methods section appears last rather than second. Perhaps we should call this *IRDAM*. In some journals, details regarding methods commonly appear in figure captions.

The basic IMRAD order is so eminently logical that, increasingly, it is used for many other types of expository writing. Whether one is writing an article about chemistry, archaeology, economics, or crime in the streets, the IMRAD format is often the best choice.

This point is generally true for papers reporting laboratory studies and other experiments. There are, of course, exceptions. As examples, reports of field studies in the earth sciences and many clinical case reports in the medical sciences do not readily lend themselves to this kind of organization. However, even in these descriptive papers, the same logical progression from problem to solution is often appropriate.

Occasionally, the organization of laboratory papers must differ. If a number of methods were used to achieve directly related results, it might be desirable to combine the materials and methods and the results into an integrated experimental section. In some fields and for some types of results, a combined results and discussion section is usual or desirable. In addition, many primary journals publish notes or short communications in which the IMRAD organization is modified.

Various types of organization are used in descriptive areas of science. To determine how to organize such papers and which general headings to use, refer to the instructions to authors of your target journal and look at analogous papers that the journal has published. Also, you can obtain general information from appropriate source books. For example, types of medical papers are described by Huth (1999), Peat and others (2002), Taylor (2018), and contributors to a multiauthor guide (Hall 2013); types of engineering papers and reports are outlined by Michaelson (1990) and by Beer and McMurrey (2019). Indeed, even if a paper will appear in the IMRAD format, books on writing in one's own discipline can be worth consulting. Examples of such books include those in biomedical science by Zeiger (2000); the health sciences by Lang (2010); chemistry by Ebel, Bliefert, and Russey (2004); and psychology by Sternberg and Sternberg (2016).

In short, the preparation of a scientific paper has less to do with literary skill than with *organization*. A scientific paper is not literature. The preparer of a scientific paper is not an author in the literary sense. As an international colleague noted, this fact can comfort those writing scientific papers in other than their native language.

Some old-fashioned colleagues think that scientific papers should be literature, the style and flair of an author should be clearly evident, and variations in style encourage the interest of the reader. Scientists should indeed be interested in reading literature, and perhaps even in writing literature, but the communication of research results is a more prosaic procedure. As Booth (1981) put it, “Grandiloquence has no place in scientific writing.”

Today, the average scientist, to keep up with a field, must examine the data reported in very many papers. Also, English, the international language of science, is a second language for many scientists. Therefore, scientists (and, of course, editors) must demand a system of reporting data that is uniform, concise, and readily understandable.

SHAPE OF A SCIENTIFIC PAPER

Imagine that a friend visits your laboratory or office. The friend is unfamiliar with your research and wants to know about it. To orient your friend, first you identify your general research area and say why it is important. Then you state the specific focus of your research, summarize how you gathered your data, and say what you found. Finally, you discuss the broader significance of your

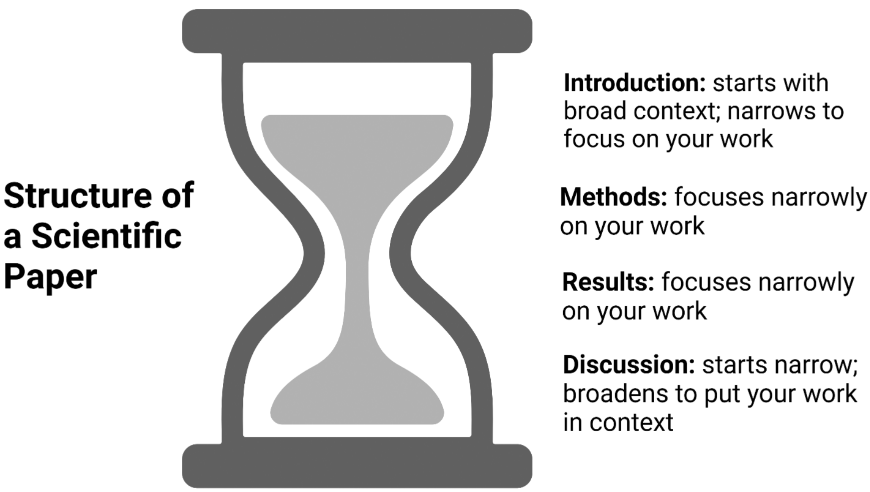

Figure 4.1. (Created with BioRender.com)

findings. The friend now has a new understanding—and, if you are lucky, the friend might buy you lunch.

Although intended for readers who are more knowledgeable, a scientific paper should take much the same approach: first provide a broad orientation, next focus narrowly on the specific research, and then consider the findings in a wider context. Some have likened this shape for a scientific paper to an hourglass: broad, then narrow, then broad. Keeping this overall structure in mind can aid when writing the individual parts of a paper and integrating them into a coherent whole.

OTHER DEFINITIONS

If *scientific paper* is the term for an original research report, how should this be distinguished from research reports that are not original, are not scientific, or somehow do not qualify as scientific papers? Some specific terms are commonly used: *review paper* (or *review article*), *conference report,* and *meeting abstract*.

A review paper typically reviews the recent work in a defined subject area. Thus, it is designed to summarize, analyze, evaluate, and synthesize information that *has already been published* (research reports in primary journals). Although much or all of the material in a review paper has previously been published, the problem of dual publication (duplicate publication of original data) does not normally arise because the review nature of the work is usually obvious—often from the title of the periodical, such as *Microbiology and Molecular Biology Reviews* or *Annual Review of Astronomy and Astrophysics*. Do not assume, however, that reviews contain nothing new. From the best review papers come new syntheses, new ideas and theories, and even new paradigms.

A conference report is a paper published in a book or journal as part of the proceedings of a symposium, national or international congress, workshop, roundtable, or similar meeting. Such conferences commonly are not designed for the definitive presentation of original data, and the resultant proceedings (in a book or journal) do not qualify as primary publications. Conference presentations often are review papers, presenting reviews of the recent work of particular scientists or recent work in particular laboratories. Material at some conferences (especially the exciting ones) takes the form of preliminary reports in which new, original data are presented, often accompanied by interesting speculation. But usually, these preliminary reports do not qualify, nor are they intended to qualify, as scientific papers. Later, often much later, such work may be validly published in a primary journal; by this time, the loose ends have been tied down, essential experimental details have been described (so that a competent worker could repeat the experiments), and previous speculation has matured into conclusions.

Therefore, the vast conference literature that appears normally is not *primary*. If original data are presented in such contributions, the data can and should be published (or republished) in an archival (primary) journal. Otherwise, the information may essentially be lost. If publication in a primary journal follows publication in a conference report, permission from the original publisher may be needed to reprint figures and other items (see Chapter 19, "Rights and Permissions"); however, the more fundamental problem of dual publication normally does not and should not arise.

Meeting abstracts may be brief or relatively extensive. Although they can and generally do contain original information, they are not primary publications. Therefore, publication of an abstract should not preclude publication of the full report later.

Traditionally, there was little confusion regarding the typical one-paragraph abstracts published as part of the program or distributed along with the program at a national meeting or international congress. It was usually understood that many of the papers presented at these meetings would later be submitted for publication in primary journals. Sometimes conference organizers request extended abstracts (or *synoptics*). The extended abstract can supply almost as much information as a full paper; mainly it lacks the experimental detail. However, precisely because it lacks experimental detail, it cannot qualify as a scientific paper.

Those involved with publishing these materials should see the importance of carefully defining the various types of papers. More and more publishers, conference organizers, and individual scientists have agreed on these basic definitions, and their general acceptance can greatly clarify both primary and secondary communication of scientific information.