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An Overview of Writing and Publishing in the Health Sciences

The profound, if unacknowledged, truth is that *science could not exist without writing*. The characteristics that make science science—that it is public, objective, reproducible, predictive, cumulative, and systematic—all depend on written communication. Science simply cannot be sustained with oral or visual communication. Further, *publication is the final stage of research*. If the results are not published, from a scientific standpoint, the research never took place. Publication marks the beginning of the formal debate about the research and is usually the most lasting if not the only record of the research. Thus, writing is integral to science and to those who depend on it.

In the clinical sciences, the concept of evidence-based medicine also depends on writing: evidence-based medicine is *literature-based medicine*. That is, the evidence needed to support clinical decisions is compiled from published reports of research. In turn, the quality of these reports depends to a large extent on how well the research is described. Again, writing is what makes evidenced-based medicine possible.

At the same time, scientific *writing* is not only about writing. It is also about correctly *documenting* research protocols,

“Pale ink is better than the most retentive memory.”

—Chinese philosopher and sage, Confucius (551–479 BCE)

analytical methods, and results. It is about *communicating* with graphs, tables, numbers, images, and graphic design, as well as with words. It is about *persuading* readers to choose one option over another on the basis of fact and logic, as opposed to supposition and emotion. It is about *archiving* the results, conclusions, and lessons learned from doing research so that others can build on those lessons.

In this chapter, I provide an overview of writing and publishing in the sciences, particularly in the biomedical sciences. Much of this book, and indeed, much of science, is concerned with publishing in scientific journals. I begin by summarizing the history of the scientific journal, identifying some key events in its development, and close with some thoughts on its future.

A Brief History of Scientific Publications

The First Scientific Journals

Western science began in ancient Greece, where the search for the principles of nature was combined with the principles of argumentation for presenting ideas⁽¹⁾. For the next several centuries, medical texts could be roughly classified as academic treatises (writings on topics such as bloodletting or ophthalmology, for example), surgical texts (including anatomical descriptions), and remedybooks (instructions for preparing potions and charms, as well as herbal medicines and advice on healthy living)⁽²⁾. As generations of scribes translated and copied these texts, information was often introduced, omitted, or rearranged. Thus, each text could differ greatly from previous and concurrent copies in content and authorship, as well as in appearance, materials, dimensions, style of script, spelling, and so on. Not until 1450, when Johann Gutenberg introduced the printing press, did standardization become possible⁽³⁾.

Aside from the printing press, which made possible modern scientific publishing, scientific journals arose from the marriage of two developments in the 1500s: newspapers and scientific societies⁽⁴⁾. Scientific publishing itself began January 5, 1665, when the French published the first scientific journal, the *Journal des scavans*. Not to be outdone, 4 months later (May 6, if you care) the British began publishing the *Proceedings of the Royal Society*. The British point out that the French publication was actually a review of the major books of the time, whereas

Ages and Key Events in the History of Biomedical Writing and Scientific Publishing

Antiquity

Thoth (Egypt's ibis-headed or baboon-headed god), mythical inventor of writing—and the patron god of physicians.

Apollo, Greek god of rhetoric and the arts, gives the gift of healing to his favorite son, Asclepius.

Age I: The Great Medical Texts

Before the Common Era (BCE; formerly BC)

- 4000** Writing develops in the Middle East. Periods before this time are referred to as “prehistory”; those after it, “history.”
- 1700** Earliest known Egyptian medical text, the *Papyrus Smith*, describes diseases by presentation, treatment, and prognosis.
- 1600** Another early Egyptian text, the *Papyrus Ebers*, contains the oldest known case histories.
- 1600** Chinese develop their ideographic script.
- 900** *Ayurveda* is written, describing this ancient system of health care in India.
- 850** The Mesha Stele, a stone tablet inscribed in the Moabite language, is the first text to use punctuation.
- 800** The Greek consonantal-vowel alphabet is created.
- 460** Hippocrates writes 70 books on medicine.
- 300** *Nei Ching* (Yellow Emperor's Book of Medicine) is written in China, reflecting several centuries of medical practice.

Age II: The Great Physician Writers

The Common Era (CE; Formerly AD)

- 20** Celsus writes *De Re Medica* (an 8-volume encyclopedia of medicine).
- 170** Galen writes 500 books on medicine.
- 400** The forerunner to the modern bound book, the parchment codex, is introduced.
- 885** Al-Razi, the leading Islamic physician, writes *Kitab Al-Mansuri*, a 10-volume treatise on Greek medicine, helping to preserve these teachings.
- 1020** Ibn Sina (Avicenna) writes “*Al-Qanun fi al-Tibb*” (*The Canon of Medicine*), the standard medical text in Europe and the Middle East for almost 500 years.
- 1090** Trotula di Ruggiero, a woman physician, writes several influential books on women's medicine.
- 1180** Maimonides (Moses ben Maimon), influential Jewish philosopher and physician, writes 10 important monographs on Greek and Middle Eastern medicine.
- 1300** Taddeo Alderotti writes *Consilia* (medical case book), which contains the first modern case histories.
- 1363** The most complete and scholarly book on surgery to date, the *Inventarium sive Chirurgi Magna*, is written by Guy de Chauliac, physician to Pope Clement VI.
- 1440** Johann Gutenberg invents the printing press.

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“If men learn this [writing], it will implant forgetfulness in their souls; they will cease to exercise memory because they will rely on that which is written.”

—Socrates, quoted by Plato, 300 BCE

the *Proceedings* published original research and established a form of peer review as a requirement for publication. (However, the earliest account of blinded peer review as we know it today is described in the preface to the French edition of *Medical Essays and Observations*, published by a “Society in Edinburgh” in 1731 (5). Both the *Journal des scavans* (later renamed *Journal des savants*) and the *Proceedings of the Royal Society* are still published.

Not until 1679 did the world see the first scientific journal devoted exclusively to medicine: *Nouvelles Découvertes sur Toutes les Parties de la Médecine*. The first American journal devoted exclusively to medicine, *The Medical Repository*, was published in New York in 1797. Like most early journals, it lasted only a few years. In 1812, *The New England Journal of Medicine and Surgery and the Collateral Branches of Science* began to be published in Boston. Known today simply as *The New England Journal of Medicine*, it is published by the Massachusetts Medical Society, making it officially a regional medical journal, albeit one with a worldwide reputation. It is the oldest continuously published medical journal.

The Development of the Scientific Article

In 1859, a young French chemist took up a challenge by the French Academy of Sciences to devise the most innovative experiment for testing the theory of spontaneous generation. This theory held that living organisms could arise “spontaneously” from non-living matter. The chemist won the award, his research virtually ending debate on spontaneous generation and helping to establish the germ theory of disease (6).

However, when the chemist published his award-winning research, he described his experimental methods (which, after all, was what the challenge was all about), and thus was the first to add what became the Methods section to the scientific article. Thus, among all of Louis Pasteur’s contributions to science—in fields as diverse as crystals, optics, silkworm diseases, sterilization, and vaccines against anthrax and rabies—his introduction of the Methods section to the scientific article is perhaps his most important because it has affected all branches of science.

Today, we know the form of the scientific article as the **IMRAD** (pronounced “im-rad”) **format**: Introduction, Methods, Results, and Discussion. In 1972, the American National Standards

Ages and Key Events in the History of Biomedical Writing and Scientific Publishing (*continued*)

- 1500** Italian scholar Aldus Manutius begins to develop typography: he invents italic type, the semicolon, and the modern comma and popularizes the practice of ending sentences with a period.
- 1516** Johann Froben publishes Erasmus' *New Testament*, the first book to use page numbers, which improved indexing, annotation, and cross-referencing.
- 1542** Vesalius writes *De Humani Corporis Fabrica* (On the Fabric of the Human Body) which contains more than 600 woodcut illustrations of human dissection.
- 1604** Robert Cawdrey publishes the first English dictionary, *A Table Alphabeticall of Hard Words*. Its 100 pages contain 3000 words.
- 1609** The Italian *Accademia dei Lincei* publishes the proceedings of its meetings as *Gesta Lynceorum*, the first publication of any scientific society.
- 1665** Robert Hooke publishes *Micrographia*, illustrated with the first drawings of microscopic organisms.

Age III: Formalized Medical Writing

- 1665** First scientific journals are published: the French *Journal des sçavans* and the English *Proceedings of the Royal Society*.
- 1669** Christiaan Huygens creates perhaps the earliest known graph, a plot of the expected number of survivors from a hypothetical pool of 100 persons, as a function of age.
- 1679** The first journal devoted exclusively to medicine, *Nouvelles Découvertes sur Toutes les Parties de la Médecine*, begins publication. It had four titles in the 4 years it was published.
- 1731** The modern peer review process is first described.
- 1740** Albert von Haller of the University of Gottingen creates the first comprehensive catalog of medical periodicals.
- 1755** Samuel Johnson publishes the first comprehensive dictionary in English, *Dictionary of the English Language*. It defines 43,000 words and contains 114,000 supporting quotations.
- 1762** First medical library in the US is established at Pennsylvania hospital in Philadelphia.
- 1786** William Playfair publishes the first statistical graphs in his book, *The Commercial and Political Atlas*. The book introduced the time-series line graph, bar chart, pie chart, and circle chart.
- 1797** First American medical journal, *The Medical Repository*, is published in New York. It lasts only a few years.
- 1812** *The New England Journal of Medicine*, the oldest continuously published medical journal in the world, begins as *The New England Journal of Medicine and Surgery and the Collateral Branches of Science*.
- 1823** *The Lancet* begins publication in London.
- 1859** Pasteur adds the Methods section to the scientific article, essentially creating the IMRAD format.
- 1865** American John Shaw Billings, MD, develops what will become *Index Medicus*, a comprehensive index to the medical literature. He also establishes what will become the US National Library of Medicine.
- 1867** First commercially successful typewriter is invented by Christopher Sholes, Carlos Glidden, and Samuel W. Soule.
- 1883** *The Journal of the American Medical Association* (now *JAMA*) begins publication.

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“The Journal was invented for the relief of those either too indolent or too occupied to read whole books ... It is a means of satisfying curiosity and becoming learned with little trouble.”

French writer and founder of the first scientific journal, Le journal des scavans, Denis De Sallo (1626–1669)

Institute (ANSI) published standard Z39, which established IMRAD as a national standard for reporting scientific information⁽⁷⁾. The revised standard, Z39.18, is now accepted worldwide.

The Beginnings of Organized Biomedical Writing and Publishing

In the early 1900s, writing for medical journals began to coalesce as a distinct body of knowledge. The oldest book published in the US that I could find with “medical writing” in its title is *Suggestions to Medical Writers*, by George M. Gould, AM, MD, which was published in 1900⁽⁸⁾. After publication of two versions of *Suggestions for Authors* by the American Medical Association in 1910 and 1922, in 1925 George Simmons and Morris Fishbein, Editors of *JAMA*, published *The Art and Practice of Medical Writing*, editions of which were published until 1972 and that formed the bases for the *AMA Manual of Style*, first published in 1962⁽⁹⁾.

In 1940, Harold Swanberg, MD, and his colleagues formed the **Mississippi Valley Medical Editors Association**. Swanberg had been the founding editor, in 1924, of *The Radiological Review*, and was interested in supporting the editors of medical society bulletins and small journals, as well as the physicians who contributed to these publications. The Association became the **American Medical Writers Association** in 1948⁽¹⁰⁾. Membership was limited to physicians for many years, but it now consists mostly of professional medical writers and editors who work in the areas of regulatory writing, pharmaceutical development, scientific publications, physician education, pharmaceutical marketing, public relations, and patient education, among other specialties⁽¹¹⁾. In 1982, the European Chapter of AMWA formed an independent sister organization, the **European Medical Writers Association**.

In 1957, the **Council of Biology Editors** was established by the **National Science Foundation** and the **American Institute of Biological Sciences**. Today, as the **Council of Science Editors**, the organization is an international society of editors-in-chiefs of scientific journals, as well as managing editors, manuscript editors, authors' editors, publishers, printers, and others involved in producing scientific journals⁽¹²⁾.

The next major innovation in scientific publications probably came in 1957, when the *Journal of the American Medical*

Ages and Key Events in the History of Biomedical Writing and Scientific Publishing (*continued*)

- 1890** William Dorland publishes the *American Illustrated Medical Dictionary*.
- 1898** The Medical Library Association is established.
- 1904** Statistician Karl Pearson performs the first meta-analysis, a form of secondary research in which scientific articles themselves become the data for research; now a part of evidence-based medicine.
- 1908** Thomas Stedman publishes *Stedman's Medical Dictionary*.
- 1911** German artist Max Brödel creates the first academic department of medical illustration, at the John Hopkins School of Medicine.
- 1925** George Simmons and Morris Fishbein, Editors of *JAMA*, first publish *The Art and Practice of Medical Writing*, editions of which were published until 1972.
- 1940** Mississippi Valley Medical Editors Association is founded, later to become the American Medical Writers Association (AMWA) in 1948.
- 1945** The Association of Medical Illustrators is founded.
- 1955** Eugene Garfield introduces the Impact Factor, which becomes an unintended and controversial proxy for the importance of a journal based on patterns of citations to published articles.
- 1956** The Library of the Surgeon General's Office, established in 1836, is renamed The National Library of Medicine (NLM). With more than 7 million items, NLM is the largest medical library in the world.
- 1957** Council of Biology Editors (now the Council of Science Editors) is formed.
- 1957** *JAMA* begins to provide abstracts with the articles it publishes.
- 1960** The Council of Biology Editors (now the Council of Science Editors) publishes the first edition of its style manual, *Style Manual for Biological Journals* (now *Scientific Style and Format*).
- 1962** The American Medical Association publishes the first edition of what will become the *AMA Manual of Style*.
- 1972** American National Standards Institute adopts Standard Z39, establishing IMRAD as the official standard for presenting scientific information.
- 1973** The Association for Scientific Journals is formed, with the support of the Institute of Electrical and Electronics Engineers (IEEE), to disband in 1977 and to re-emerge as the Society for Scholarly Publishing in 1978.
- 1974** The National Science Foundation sponsors the Innovation Guide Project to study ways to make scientific publishing more efficient. In 1978, the Project is combined with The Association for Scientific Journals to form The Society for Scholarly Publishing.
- 1977** Statistician John Tukey publishes *Exploratory Data Analysis*, a major advancement in statistical graphics; the book introduces the box plot, among other innovations.
- 1979** *Uniform Requirements for Manuscripts Submitted to Biomedical Journals* is introduced by the International Committee of Medical Journal Editors (the Vancouver Group).
- 1982** The European Association of Science Editors (EASE) is founded.
- 1984** The *New England Journal of Medicine* begins publishing financial conflict-of-interest statements.
- 1987** *Annals of Internal Medicine* introduces the structured abstract.

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Association (now *JAMA*), began to routinely include abstracts with its articles. After World War II, all the sciences experienced unprecedented growth, which increased both the number of scientific journals and the number of articles published in them. The number of articles available to clinicians and researchers became so great that readers had to be far more selective than ever before. Abstracts helped them select the articles they needed to read and to avoid those they didn't, a function they continue to serve today.

In 1968, Ms. Augusta Litwer, a secretary to an eminent nephrologist at the University of Washington in Seattle, grew tired of retyping articles that had been rejected by one journal to prepare them for submission to another, with a different formatting and reference style. She wrote to the editors of the *Annals of Internal Medicine*, the *Journal of the American Medical Association*, and the *New England Journal of Medicine* and asked them to consider standardizing their requirements.⁽¹³⁾

Ten years later, Ed Huth, Editor, *Annals of Internal Medicine*; Stephen Lock, Editor, *British Medical Journal*; John Murray, Editor, *American Review of Respiratory Disease*; and Therese Southgate of *JAMA*, organized a meeting of medical journal editors in Vancouver, British Columbia, to discuss Ms. Litwer's idea. The resulting International Steering Committee later changed its name to the **International Committee of Medical Journal Editors (ICMJE)**. However, because of its original meeting place, the ICMJE is still often referred to as **the Vancouver group**.

The result of the Vancouver meeting was **The Uniform Requirements for Manuscripts Submitted to Biomedical Journals** (often shortened to the **Uniform Requirements** or referred to as the **Vancouver Style**), a set of guidelines standardizing the formatting of manuscripts submitted to biomedical journals—especially those reporting clinical research—for publication. As of January, 2008, some 650 journals around the world had adopted the *Uniform Requirements*, saving secretaries, editors, and authors all over the world considerable time and effort in preparing manuscripts⁽¹⁴⁾.

The founding of the ICMJE was followed in 1995 by the **World Association of Medical Editors** (WAME, pronounced “whammy”) as a more inclusive organization with similar goals. Members are medical journal editors and scholars from countries around the world who, primarily through online communication, foster international cooperation among editors of peer-reviewed

Ages and Key Events in the History of Biomedical Writing and Scientific Publishing (*continued*)

- 1989** The American Medical Association sponsors the First International Congress on Peer Review in Biomedical Publication.
- 1992** First completely electronic medical journal, *The Online Journal of Current Clinical Trials*, is launched by the American Academy for the Advancement of Science (AAAS) and the Online Computer Library Center (OCLC).
- 1994** Cognitive science professor Stevan Harnad proposes self-archiving of scientific articles, in which authors post their publications online where they can be read by anyone, without charge.
- 1995** WAME, the World Association of Medical Editors, a virtual organization supporting medical journal editors around the world, is formed.
- 1997** The Consolidated Standards of Reporting Trials Statement (The CONSORT Statement) for reporting randomized controlled trials; beginning of the reporting standards movement.
- 1997** US National Library of Medicine (NLM) launches PubMed, the free, online version of MEDLINE, the world's most comprehensive index to the medical literature.
- 1999** The online *Journal of Medical Internet Research (JMIR)*, one of the first open-access journals in medicine, becomes available.
- 2000** BioMed Central, a for-profit, open-access publisher is started.
- 2000** PubMed Central, an open-access, digital archive of biomedical and life science journals run by the US National Library of Medicine becomes available.
- 2003** Berlin Declaration on Open Access to Knowledge in the Sciences and Humanities is released to promote the Internet as a functional instrument for a global scientific knowledge base.
- 2004** *PloS Medicine* (Public Library of Science), an open-access medical journal, begins operations.
- 2008** The Neuroscience Peer Review Consortium allows authors to have reviews of rejected manuscripts sent to other participating journals with subsequent submission.

medical journals. Membership in WAME is free, and all decision-making editors of peer-reviewed medical journals and anyone with scholarly interests in scientific publications in any country is eligible to join⁽¹⁵⁾.

A recent experiment in peer review is the Neuroscience Peer Review Consortium, a group of journals that have agreed to share reviews of rejected articles with other participating journals. Many good articles are rejected because they do not meet the publishing needs of the journal, not because the research is poor. In such cases, authors may have the first journal forward the reviews to the second journal, which, if it accepts the reviews, can publish the article sooner because it does not have to go through a second round of reviews (see: <http://nprc.incf.org/>).

“*In the first place, the texts are full of philological and lexicographical problems, and they are written in a specialized, concise, and aphoristic style abounding in syntactical difficulties. But the greatest difficulty of all is the impossibility of translating into English the names of a great number of the maladies mentioned, and the names of most of the drugs.*”

—Warren R. Dawson, on the problems with translating, from Hieratic (a cursive script that evolved from Hieroglyphics) into German and then into English, the Papyrus Ebers, the oldest known Egyptian medical text, believed to have been written about 1500 BCE but reporting the medical folklore of the previous 20 centuries. (Had you going there for a moment, didn't it?)

Advances in Scientific Reporting and Documentation

In the 1980s, **systematic literature reviews** became popular in clinical medicine. Developed in the 1950s in the field of education, a systematic review is just that: you systematically collect all the research on a given topic, select studies according to predetermined quality criteria, abstract the same information from each included study, display the results in evidence tables, and interpret the results in light of the totality of the evidence.

In a systematic review, dozens or even hundreds of titles and abstracts are examined to determine whether the patient population, intervention, study design, or outcome variables meet the inclusion criteria for the review. However, the traditional **informative abstract** is often limited to a single paragraph of 150 words. With such short abstracts, it's difficult to determine whether an article might be suitable for inclusion: there's not a lot of information, and not a lot of standardized information, in the traditional informative abstract.

In part to address this problem, the **structured abstract** was introduced to clinical journals in 1987⁽¹⁶⁾. Using a series of headings that parallel the IMRAD headings, such as background, purpose, patients, interventions, outcomes, results, and conclusions, the structured abstract organizes information pertinent to screening for systematic reviews and general readers alike and expands the content to 250 words. This combination of increased length and standardized, organized information improves the accuracy with which articles can be screened by any reader.

In clinical medicine, systematic reviews became part of the **evidence-based medicine movement** that arose in the 1990s. A consequence of reviewing the literature closely was the realization that much research was so poorly conducted or reported (or both) that the published conclusions were unreliable. Since the introduction of hypothesis testing to the medical literature in the 1930s, hundreds of studies of statistical errors in the clinical literature have been published. Most of these studies are reviews of articles from top-tier journals published in developed countries, and the reviews have been conducted in all branches of medicine. The vast majority of these reviews find that often more than 50% of the articles presenting statistical analyses contain methodological or statistical reporting errors, many serious enough to call the authors' conclusions into question. In fact, the problem of poor statistical reporting is long-standing, wide-

spread, potentially serious, and yet largely unknown in the medical community⁽¹⁷⁾.

The first comprehensive set of **statistical reporting guidelines** was published in 1997, by an obscure medical writer and a junior statistician from the Cleveland Clinic (that is, me, and my colleague and co-author, Michelle Secic). As a medical writer-editor, I wanted to know something about interpreting and reporting statistics. The major style manuals had nothing on statistical reporting (other than that the “*P*” in P value should be capitalized and italicized. I was hoping for more.). The major books on writing and publishing in scientific journals also had nothing on the topic. Eventually, I systematically collected the studies of statistical errors mentioned above, synthesized them into a set of reporting guidelines, and published them as a book, *How To Report Statistics in Medicine: Annotated Guidelines for Authors, Editors, and Reviewers* (published by the American College of Physicians in 1997; 2nd edition published in 2006)⁽¹⁷⁾.

Another response to the poor reporting of clinical research by a few meta-analysts, journal editors, and researchers was what I call the **standards movement**, which began in 1997 with the publication of the **CONSORT Statement** for reporting randomized trials⁽¹⁸⁾. The CONSORT Statement (short for the CONSolidated Standards Of Reporting Trials) consists of a checklist of 22 items (but asking 46 specific questions) that need to be addressed in manuscripts reporting randomized trials. Journals adopting the CONSORT Statement require the completed checklist to be submitted with the manuscript because it ensures that the most important aspects of the trial have been addressed and speeds the peer review process by indicating the page number of the manuscript on which each aspect is described.

The CONSORT Statement became a model for several similar efforts:

- The **QUOROM Statement** (Quality of Reporting of Meta-analyses) for reporting meta-analyses of randomized trials (recently revised to the **PRISMA Statement**, for Preferred Reporting Items for Systematic reviews and Meta-Analyses)⁽¹⁹⁾
- The **STROBE Statement** (Strengthening the Reporting of Observational Studies in Epidemiology)⁽²⁰⁾
- The **TREND Statement** (Transparent Reporting of Evaluations with Nonrandomized Designs)⁽²¹⁾

- The **MOOSE Statement** (Meta-analysis of Observational Studies in Epidemiology)⁽²²⁾
- The **STARD Statement** (Standards for Accurate Reporting of Diagnostic Tests)⁽²³⁾
- The **ORION Statement** (Outbreak Reports and Intervention studies of Nosocomial infection)⁽²⁴⁾
- The **STREGA Statement** (STrengthening the REporting of Genetic Association Studies)⁽²⁵⁾

These and other guidelines can now be accessed through the **EQUATOR initiative** (Enhancing the QUALity and Transparency Of health Research)⁽²⁶⁾. EQUATOR is an umbrella organization for developers of reporting guidelines, medical journal editors, peer reviewers, research funding bodies, and others interested in improving the quality of research and research publications.

Although reporting standards have been established for clinical research, few such standards appear to exist for reporting basic science. In my research for this book, I found no studies evaluating the adequacy of articles reporting laboratory results or procedures and no guidelines for reporting these results or procedures in scientific journals. Such guidelines would seem to be necessary to ensure accurate, complete, and consistent documentation in the literature and thus communication with readers.

However, proposing comprehensive reporting guidelines for the basic sciences is a subject for another book (and by another author). In Chapter 10 of this book, I propose only preliminary guidelines for documenting laboratory images, such as blots, gels, and micrographs, as well as clinical images that likewise currently have no reporting guidelines, such as echocardiograms, radiographs, and CT scans. Biomedical images are part of the data on which conclusions are based, and their interpretation is often subjective. Thus, documenting the circumstances of their acquisition and identifying the features that support a given interpretation are critical in scientific communication.

The basic sciences are, however, developing reporting standards for the archiving and sharing of data, especially the ultra-large data sets associated with genetic and proteomic research. **Proteomics** (the large-scale study of the structures and functions of proteins), **genomics** (the study of an organism's entire genetic makeup), and the analysis of **microarrays** (small chips containing tens of thousands of microscopic DNA segments used to identify various genes) all generate large amounts of data.

In particular, the **Minimum Information for Biological and Biomedical Investigations (MIBBI)** initiative is coordinating several such projects⁽²⁷⁾. The MIBBI project began in 2006 through the joint efforts of the **Proteomics Standards Initiative**, the **Genomic Standards Consortium**, the **Microarray and Gene Expression Data Society (MGED)**, and the **Reporting Structure for Biological Investigations Working Groups**. For example, the MGED supports the **Minimum Information About a Microarray Experiment (MIAME)** project that identifies the information needed to interpret the results of the experiment and potentially to reproduce the experiment⁽²⁸⁾.

Types of Scientific Articles

Scientific studies can be divided into four broad categories of investigation—namely, those that attempt to *describe*, *explain*, *predict*, or *manipulate* the physical world. Over the past four centuries, five types of scientific articles have emerged to record these studies: observational, theoretical, experimental, methodological, and review. These types are still the mainstays of scientific publishing.

Observational Articles

Science begins with observation and description. One of the primary activities in basic science is developing ways to observe structures and processes that are beyond our normal sensory capacities. Observation soon gives rise to description and then measurement so that what is observed can be described and defined in objective, reproducible terms. In turn, measurement allows analysis and experimentation. Quantitative and qualitative analyses are fundamentally descriptive procedures that allow us to “observe” the nature of physical reality at various levels of detail under various conditions.

Within clinical medical science, the most important observational articles are case reports, case series, cross-sectional studies, and epidemiological studies, including case-control and cohort studies.

A **case report** consists of observations on a single patient. In one sense, the case report is the foundation of medicine: it is a record of the assessment of a patient’s illness or disability. Case reports of rare conditions, unusual presentations of common

problems, or important clinical or pathological findings or events can obviously be of interest. The case report describing the first total laryngeal transplant described a major medical advance, for example. In another sense, observations on a single patient may be hard to put in perspective. Case reports describing adverse drug reactions, by themselves, may not be particularly useful or newsworthy⁽²⁹⁾. Medical curiosities are also published as case reports, even when they have limited clinical implications (“Ulcerative Nintendinitis: Repetitive Strain Injury from Playing Computer Games”).

Important publishable case reports are rare. Although case reports are relatively easy to prepare when you are early in your career, they are likely to be unremarkable and therefore difficult to publish in most journals. (If you have to write one as part of your training, however, see *Clinical Case Reporting in Evidence-Based Medicine*, by Milos Jenick^[30]). Nonetheless, some new journals publish case reports exclusively: *Cases Journal* (www.casesjournal.com) and the *Journal of Medical Case Reports* (www.jmedicalcasereports.com) are rapid-peer-reviewed, open-access journals published by the Science Navigation Group (see also: <http://www.casesnetwork.com/>); *BMJ Case Reports* is published by the British Medical Association (casereports.bmj.com); and the *Journal of Radiology Case Reports* is an open-access, interactive journal published by EduRad, a non-profit organization that promotes education in medicine and radiology (<http://www.radiologycases.com/index.php/radiologycases>).

Case series are collections of observations on two or more patients. Case series are useful for describing rare diseases or new or unusual outbreaks of disease. The clinical condition now known as AIDS was first described in a case series. Like case reports, however, good, publishable case series are rare, so you should think twice about spending the time to write them to meet a publication requirement.

Cross-sectional studies include several ways of gathering data at a single point in time, such as mail surveys, telephone interviews, structured face-to-face interviews, standardized tests, clinically oriented questionnaires (e.g., to measure quality of life or the likelihood of mental illness), medical chart reviews, or database studies. Cross-sectional studies can establish the prevalence of a condition, investigate associations among variables, and, when repeated over time, track changes in a population.

Case-control studies retrospectively and systematically identify people from the same population with and without an outcome of interest (such as a disease, an injury, or a complication of therapy) and compare their histories of exposure to identify factors that might be associated with causing or preventing the outcome. Researchers may have direct contact with patients or they may analyze existing data from large health care databases, clinical registries, or other historical sources.

Cohort studies involve observing a group of subjects forward in time until at least some experience the outcome of interest. Those with and without the outcome are then compared to determine potential causative or protective factors. Such studies are uniquely suited for detecting the frequency with which new cases of a disease or disability occur in a population.

Theoretical Articles

Theoretical articles attempt to identify the underlying laws and principles of physical, biological, or social phenomena. Good theories are consistent with the data, have good explanatory and predictive power, and are generative; that is, they suggest new approaches to studying phenomena. Theories and principles must also be testable and capable of being supported or refuted on the basis of data.

Experimental Articles

Experimental articles report research that tests the implications of change or variability in one part of a system on other parts of the system. Experimental results provide the basis for formulating explanations, making predictions, and eventually, affecting outcomes.

In clinical medicine, the most important experimental articles are those reporting original research on treatments, especially randomized controlled trials. **Randomized controlled trials (RCTs)** are experimental studies that provide the best protection against error, confounding, and bias and are thus preferred for testing the efficacy of interventions. Random assignment, blinding patients and study personnel to group assignment, often with the aid of placebo interventions, and conservative statistical assumptions are common features of RCTs that help protect against intentional and unintentional biases. Because the US

“A drug is any substance that, when injected into a rat, results in a scientific article.”

—Author unknown but believed to be a cynical journal editor

Food and Drug Administration requires two successful “pivotal studies” of efficacy before approving a new drug, RCTs are widely used in pharmaceutical development.

Methodological Articles

Methodological articles report technical advances in research methods and tools, such as new measurement or analytical techniques, new surgical approaches, new statistical methods, and so on. Science is advanced in part by new technologies, whose development, evaluation, and applications are reported in methodological articles.

Review Articles

Two types of review articles are commonly found in journals: traditional narrative review articles and systematic review articles. A **narrative review article** is usually written by an expert at the request of a journal editor. The expert relies on his or her own experience and on articles chosen by personal preference when summarizing the topic. Narrative reviews are rarely reproducible, however, because different experts have different experiences, read different journals, and base their conclusions on different information from different articles. Some narrative reviews are broad introductions or overviews, similar to, say, textbook chapters, whereas others present highly focused, detailed, and current accounts of a topic.

In contrast, a **systematic review article** is compiled through a formal, reproducible procedure specified in advance of data collection; it is a specific research method. Researchers systematically identify and collect all the articles that test the same hypothesis, systematically abstract the same data from these articles, systematically display the data in one or more evidence tables, and then interpret the evidence. Under some circumstances, the numerical results of the included studies can be combined statistically in a **meta-analysis**.

Systematic reviews should be of special interest to biomedical professionals early in their careers. Many clinicians and researchers are required to publish at least one paper as part of their training, yet they rarely have the money, expertise, resources, insight, or supervision to conduct important original research, nor are they able to compete successfully for most research grants. Systematic reviews, however, allow even relatively new researchers to ask and

answer important questions and to publish the results in leading journals⁽³¹⁾. (See the **Appendix** for a more detailed discussion of the value of systematic reviews in science education.)

Other Forms of Communication in Journals

Brief Communications are short reports of important findings that may be published sooner than a full article. Such communications may be longer than a letter but shorter than a full article. They tend not to include detailed methods and results and are limited to, say, 750 words and to two or three tables or figures.

Most journals cannot do without editorials and letters, which provide important and timely forums for opinion and debate.

Editorials or **commentaries** are usually commissioned by journal editors, but they may also be submitted in response to current events or recently published articles or to initiate discussions about controversial topics. **Letters to the editor** are just that: short letters addressed to the editor of a journal making one or two main points. Such letters may be critiques of recently published articles, opinions on current professional issues, or announcements of new research initiatives, for example.

Finally, many journals also publish a variety of other communications, such as book reviews, essays, news items, meeting notices or summaries, calendars of events, classified advertisements, and sometimes even obituaries, poetry, inspirational photographs, or interesting scientific images. Some journals, such as the BMJ (the *British Medical Journal*) and the *Public Library of Science*, now also sponsor blogs on their websites where anyone can comment on published articles and current topics, debate issues, and otherwise interact with other users of the blog.

Types of Journals

Journals are often characterized as **archival journals**, which seek to publish the most important original research; **review journals**, which summarize research on various topics; **applied journals**, which are dedicated to improving the delivery of health care (such as journals of continuing medical education) or the practice of laboratory science; and non-subscription, **controlled-circulation journals** (or **tabloids** or “**throw-aways**”), which publish current news items, promote travel destinations, feature human-interest articles, and so on, primarily to draw readers within viewing range of advertisements.

“ Somehow the assumption has crept in that just because a doctor is a good physician or researcher he can do as well in other fields, no matter how unlike they may be to his own successful field... Let me remind you that writing is a specialized field... It takes countless hours of practice in the art, in the techniques, in the work of writing.”

—Associate Professor of Journalism, University of Missouri, J. Linwood Cutler, 1957

Within archival journals are **general medical journals** (such as *The Lancet* and *Annals of Internal Medicine*) and **general science journals** (such as *Nature* and *Science*), which are directed to the larger medical and biomedical research communities; and **specialty** and **subspecialty journals**, which focus on progressively narrower aspects of a field (for example, *Surgery* is general surgical journal, *Orthopedic Clinics of North America* is a specialty journal in orthopedic surgery, and the *Journal of Knee Surgery* is a subspecialty journal within orthopedic surgery.)

Each of the journal categories above can be further divided into the so-called “first-tier,” “second-tier,” and “third-tier” journals, in order of their perceived importance. (Chapter 11 discusses journal rankings.) Despite the lack of formal definitions for these subdivisions, clinicians and researchers in each discipline soon learn which journals are in each tier. That is, each discipline has its own hierarchy of journals, ranked by prestige. One measure of professional advancement is to publish in progressively more important journals.

I should also mention what is known universally as the ***Journal of Last Resort***, which is the journal in every field that will publish almost anything, often articles that have been rejected by other journals. The *Journal of Last Resort* should not be confused with the ***Journal of Irreproducible Results*** (www.jir.com), which is a wonderful parody of the trials and tribulations of scientists. (In its own words: “*JIR* targets hypocrisy, arrogance, and ostentatious sesquipedalian circumlocution. We’re a friendly escape from the harsh and the hassle. *JIR* makes you feel good.”)

Electronic Publications

Online Journals

In 1992, the American Academy for the Advancement of Science (AAAS) and the Online Computer Library Center (OCLC) launched the first completely online medical journal, *The Online Journal of Current Clinical Trials*. The advantages of the new journal—which we now take for granted—were listed in the news release:

- Readers will be able to access published articles within 48 hours after their acceptance by the journal.
- All readers will have access to new articles at the same time; there will be no press “embargo” as there is with print journals.

- Readers can search for articles containing any words or combinations of words in any section of the article.
- Readers can automatically be notified of letters, rebuttals, or retractions related to articles in the journal.
- Readers can follow links to the abstracts of references cited in the article.
- Readers can enlarge the pages for easier reading.
- Readers can immediately obtain downloaded or faxed copies of articles, sometimes for free but often for an additional charge.
- Readers can sign up for automatic fax or mail notification about articles in fields of interest to them.

Although there are completely online journals, such as the journals published by BioMed Central, electronic publishing usually supplements traditional print publishing. The vast majority of print journals have websites, if not an associated online version. The online version may be available to members of the sponsoring society without charge and to nonmembers on an article-by-article basis for a fee. Increasingly, journals are requiring manuscripts to be submitted online, where they are logged into integrated manuscript-tracking programs that facilitate manuscript registration, peer review, copy-editing and coding, author review, and print and electronic publishing.

Another example of an electronic journal is the *Journal of Visualized Experiments* (JoVE; www.jove.com), a new peer-reviewed, indexed (in PubMed), open-access, online video journal of biological research and laboratory procedures. It was created to present experiments with greater detail and clarity than is possible in print journals and to reduce the time needed to learn new and complex experimental techniques. “Video-Articles” present step-by-step demonstrations of the experiment and a short discussion by the authors about the technique. Invited “Video-Interviews” feature leading researchers who provide a more global view of the research.

Electronic journals have no printing or mailing costs, although the digital file of the manuscript must be coded for online viewing, and they do not take up scarce and expensive shelf space in libraries. Without a physical, bound journal, however, electronic journals pose some archiving challenges. Print journals have lasted for hundreds of years, and the technology of physically accessing them—removing the volume from the shelf and

“While one can effortlessly read the text in the 300-year-old *Journal des savans*, interplanetary spacecraft recordings on magnetic media are now incomplete only 20 years after their creation. Even commercial digital conservation companies acknowledge the short life-span of 50 to 100 years for optical disks.”

—Author of *The Scholarly Journal*,
Karen L. MacDonell,
1999

turning the pages—is not likely to change. Digital storage and access is not nearly so simple. Where the actual files will be kept and how they will be preserved may be problematic. Experience has shown that electronic files must be updated periodically into the current digital format and onto the current storage media, or old technology must be maintained to read out-dated formats and media.

Preprint Servers

A traditional **preprint** is a draft of a scientific paper that has not yet been published in a scientific journal. Preprints are circulated among colleagues in an informal peer-review process before being formally submitted to a journal. A **preprint server** is a website where authors can post preprints of their manuscripts (sometimes called **e-prints**) for anyone to review. Preprint servers thus offer a dynamic exchange of information about research results before publication that may improve the quality of submitted articles. Both the National Academy of Sciences (NAS) and the Public Library of Science (PloS) maintain preprint servers. *Nature* journals “allow and encourage prior publication on recognized community preprint servers for review by other scientists in the field before formal submission to a journal. The details of the preprint server concerned and any accession numbers should be included in the cover letter accompanying submission of the manuscript to the *Nature* journal.”

Open-Access Publishing

Open-access publishing involves posting scientific articles or entire journals online, where they are publicly available from the moment of publication, without charge, and free of most copyright and licensing restrictions. The movement is driven by the desire to make scientific information widely and immediately available to scientists and the public worldwide, bypassing the traditional barriers of subscription costs and delays in printing and mailing hard copies of the journal.

In open-access publishing, the costs of processing manuscripts through peer review, editing, and coding for electronic viewing is often charged to the authors, although the fee is usually paid by their institutions or from their research grants. A variation is to make articles freely available, say, 6 months to 1 year after publication in print, which preserves the print-oriented economic

model in which advertising, with or without subscriber fees, pays for much of the cost of producing a journal.

All major open-access publishers and journals use or endorse peer review to select and refine articles. However, **open-access archives** or **repositories** do not conduct peer review, they simply post peer-reviewed articles online. Sponsored by universities, laboratories, or professional associations, archives that comply with the **Open Archives Initiative** allow users to find postings in any cooperating archive. The Initiative is a set of codes or “metadata tags” (e.g., “date,” “author,” “title,” “journal,” and so on) that allow electronic documents to be “interoperable.” That is, metadata tags allow all archived documents to be searched and retrieved as if they were all in one global collection.

Open-access journals do conduct peer review and then post the accepted articles online. As in print journals, many open-access journals are subsidized by the hosting university or professional society. They usually charge a submission or processing fee that is paid by the author or the author’s employer or funding agency. Also as in print journals, open-access journals that charge processing fees may waive them for authors in developing countries who cannot afford the fees. See <http://www.doaj.org> for a directory of open-access journals in medicine, dentistry, nursing, and public health.

Self-Archiving

Self-archiving is a form of open-access publishing in which a journal article is posted online by its authors, rather than, or in addition to, a publisher. Self-archiving sites may be operated by institutions, which post their faculty’s publications, or by other open-archive sites, such as PubMed Central. Authors are usually free to archive unpublished versions of their articles, and most journals permit authors to archive published articles as well.

Journals typically own the copyright to the articles they publish and so can legally control where the published articles appear. Journals may allow authors to post PDF files of the published article on their own or their institution’s website or on a central repository, provided that the file is not publicly available until, say, a year after publication by the journal.

Books

Books are obviously another important form of communication in the sciences. You are not likely to be approached about

“An editor is someone who separates the wheat from the chaff and then prints the chaff.”

—American politician and diplomat, Adlai Ewing Stevenson (1900–1965)

writing a book early in your career, but you may be asked to write a chapter or to assist a senior author in writing one. If so, think carefully about accepting the offer. The advantages of immersing yourself in a subject of interest must be weighed against the large amount of time involved and the relative lack of financial and professional rewards. Academic institutions rarely count books or book chapters as evidence of scholarly activity: being the first author on an article reporting original research is still the standard. On the other hand, there may be advantages in being a contributor to a well-known textbook with multiple editors. Your name may become associated with a disease or topic, and you may be invited to update your contribution in future editions, which can maintain this association over time.

You can also decide to write your own book, of course. Some authors write the book before finding a publisher because the process of researching and writing has its own rewards. Sometimes the book evolves from a series of related articles or from materials gathered or created when teaching a course, for example. Other authors prefer to find a publisher first, before going to the work of writing. They prepare a prospectus that contains a description of the book, the qualifications of the author or authors, some indication of the nature and size of the intended markets for the book, a table of contents, and a sample chapter. The prospectus is then sent to publishers for consideration.

If you decide you want to write a book (any book, but especially a scientific one), go into the project with your eyes open. Writing a book can be a rewarding experience, personally and professionally, but you are not likely to make much money. A profitable book must sell *really well* for a *long time*. Further, the publisher will usually keep 90% of the income it generates, and you will have to split the 10% royalty with your co-authors. (Royalty rates are negotiable; most publishers are reluctant to pay more than 10%, especially to first-time authors.) Thus, writing a book in the sciences is usually a labor of love and a professional contribution, not an income-generating proposition. If you are interested in writing books, by all means, investigate the Authors Guild (www.authors-guild.org/). The Guild provides its members with valuable information on interpreting the clauses of a contract and on negotiating with publishers, as well as free legal advice on publishing contracts.

The Future

The trend in scientific publications has been to develop more and more specific standards in the attempt to improve the quality, clarity, and usefulness of published research. Although journals are designed to be read by humans, they are increasingly being designed to be read by computers⁽³²⁾: computer technology, the Internet, and advances in information-processing software all promise to expand and enhance the field of scientific publishing. Innovations that hold much promise for improving biomedical research include open-access journals that make their content freely available to anyone with a computer; multimedia journals that can display and integrate text, data, video, and audio information; improved sensitivity, specificity, and scope of literature searches; and coding of content within articles and even in images at a “fine level of granularity” to allow more specific searching and computer-assisted systematic reviews and meta-analyses.

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