

CHAPTER 2

Scientific Research and Communication

It makes no sense to do research and not to communicate the results. Hence the publication of research results is an important duty for any researcher. Yet, it does not suffice to publish research: Whatever is published should be read as widely as possible. Research results are communicated and disseminated in various ways e.g., published in journals, in edited books, in monographs, presented at conferences, and circulated via blogs on the Internet. Research of great public importance may even be disseminated through television documentaries. In the context of scientific communication, there are thus three kinds of variables at play, namely documents, researchers, and cognitions, i.e., topics and ideas (Guns, 2013; Kochen, 1974).

2.1 KNOWLEDGE AND SCIENTIFIC RESEARCH

2.1.1 Tacit Versus Explicit Knowledge

According to Polanyi (1966) tacit knowledge is nonverbalized, intuitive, and unarticulated knowledge. It is knowledge that resides in a human brain and that cannot easily be codified or captured. Nevertheless it is one of the aims of the field of artificial intelligence, and in particular of expert systems, to include exactly this kind of knowledge. Explicit knowledge is that kind of knowledge that can be articulated in a formal language and transmitted among individuals. It is the kind of knowledge found in all types of scientific publications.

2.1.2 Scientific Research

This Subsection is largely based on information from Wikipedia: <http://en.wikipedia.org/wiki/Science>. Persons who spend their professional time doing science are called scientists or researchers. Note that here and further on in this work the word “science” refers not only to the natural and biomedical sciences, but also to applied science (engineering), the social sciences, and the humanities. Outsiders may ask: Why do research,

why publish research results? Is it for the benefit of humanity, out of curiosity, to increase one's social standing, to have an attractive and respected occupation, or in pursuit of recognition? We do not try to answer these questions as the answers are highly personal. Some may even do research in the secret hope of becoming famous like Einstein. However, getting rich is rarely a motivation for doing academic research.

Whatever one's field of inquiry one always has to deal with the "problem choice" the issue of choosing "good" research problems among a large amount of possibly interesting ones. Which criteria should one use to solve this question? Probably there is no general answer and being able to choose an interesting and soluble problem is just one of the characteristics that differentiates great scientists from good scientists.

Science is commonly viewed as an activity that leads to the accumulation of knowledge. Its main aim is to improve the knowledge of humanity by using scientific methods. The scientific method seeks to explain the events of nature in a logical and in most cases reproducible way (lab experiments must be reproducible but, e.g., the Big Bang is not). The use of such methods distinguishes a scientific approach from, for instance, a religious one, as supernatural explanations are never accepted in science.

Science can be described as a systematic endeavor to build and organize knowledge. Yet, performing scientific investigations differs in an essential way from following a recipe. It requires intelligence, imagination, and creativity. Research implies an inquiry process, including a problem statement, consideration of the significance of the problem, statement of the study objectives, research design, a clear and precise methodology, information about the reliability and validity of the results, appropriate data analysis, as well as a clear and logical presentation (Hernon & Schwartz, 2002).

Scientific investigations can be subdivided into different types. One distinction is between formal and empirical sciences. Formal sciences are not based on observations, but on logic and a set of axioms from which other statements (theorems) are deduced. The most important formal sciences are logic and mathematics, but theoretical computer science and formal linguistics are formal sciences as well. Most sciences are empirical sciences, including natural sciences, social sciences, and the humanities. While natural sciences study the material world and natural phenomena, the social sciences and the humanities investigate human behavior and societies. Being a scientist in the natural sciences usually leads to formulating testable explanations and predictions about the universe, followed

by performing the actual experiments or trying to observe the expected phenomena (see further on when we discuss the work of Popper). Yet, there are exceptions such as large parts of cosmology or elementary particle physics (e.g., string theory) (Woit, 2006) for which there do not (yet) exist experiments. One may say that such theories belong to a region that is part of the formal sciences, but are geared towards becoming empirical theories.

Disciplines that use science, like engineering and medicine, are referred to as applied sciences. Different engineering fields apply physics and chemistry (and possibly other fields), while medicine applies biology. Some applied fields use basic knowledge from different fields, including the formal sciences, such as genetic epidemiology which uses both biological and statistical methods, or synthetic biology which applies, among others, biotechnology and computer engineering.

Another way of describing science is through Stokes’ classification which involves Pasteur’s quadrant (Stokes, 1997). Pasteur’s quadrant is a label given to a class of scientific research methods that seek fundamental understanding of scientific problems, and, at the same time, seek to be eventually beneficial to society. Louis Pasteur’s research is thought to exemplify this type of method, which bridges the gap between “basic” and “applied” research. The term Pasteur’s quadrant was introduced by Donald Stokes in his book with the same title (Stokes, 1997). As shown in Table 2.1, scientific research can be classified according to whether it advances human knowledge by seeking a fundamental understanding of nature (basic research), or whether it is primarily motivated by the need to solve immediate problems (applied research).

The result is three distinct classes of research. Pure basic research (exemplified by the work of the atomic physicist Niels Bohr), pure applied research (exemplified by the work of the inventor Thomas

Table 2.1 Pasteur’s quadrant

		Considerations of use?	
		No	Yes
Quest for fundamental understanding	Yes	Pure basic research Bohr	Use-inspired basic research Pasteur
	No		Pure applied research Edison

Edison), and use-inspired basic research (exemplified by the work of Louis Pasteur). Actions that involve neither a search for fundamental understanding nor any considerations of use, can hardly be called “research”—hence the empty fourth cell.

Project leaders with a mindset belonging to the Pasteur quadrant are said to be the natural leaders of successful interdisciplinary work (van Rijnsoever & Hessels, 2011).

As we will occasionally refer to the nature of the scientific method we include a short description of the ideas of Karl Popper and Thomas Kuhn. According to Popper (1959) a scientific theory in the natural sciences must be empirical, which means that it is *falsifiable*. More concretely, a scientific theory leads to predictions. Falsification occurs when such a prediction (i.e., a logical consequence of the theory) is disproved either through observation of natural phenomena, or through experimentation i.e., trying to simulate natural events under controlled conditions, as appropriate to the discipline. In the observational sciences, such as astronomy or geology, a predicted observation might take the place of a controlled experiment. Popper stressed that if one singular conclusion of a theory is falsified the whole theory is falsified and must be discarded, or at least modified. If the hypothesis survived repeated testing, it may become adopted into the framework of a scientific theory. Yet, he writes:

A positive decision can only temporarily support the theory, for subsequent negative decisions may always overthrow it. So long as a theory withstands detailed and severe tests and it is not superseded by another theory in the course of scientific progress, we may say that it has “proved its mettle” or that it is “corroborated” by past experience.

Popper, 1959.

In addition to testing hypotheses, scientists may also generate a model based on observed phenomena. This is an attempt to describe or depict a phenomenon in terms of a logical, physical or mathematical representation and to generate new hypotheses that can be tested. While performing experiments to test hypotheses, scientists may have a preference for one outcome over another (called a confirmation bias), and so it is important to ensure that science as a whole can eliminate this bias. After the results of an experiment are announced or published, it is normal practice for independent researchers to double-check how the research was performed, and to follow up by performing similar experiments i.e., to

replicate the original experiments. Taken in its entirety, the scientific method allows for highly creative problem solving (Gattei, 2009).

Another important aspect of Popper's philosophy, is his theory of the three worlds or universes:

First, the world of physical objects or of physical states, secondly, the world of states of consciousness, or of mental states, or perhaps of behavioural dispositions to act, and thirdly, the world of objective contents of thought, especially of scientific or poetic thoughts and works of art.

Popper, 1972.

Clearly the information sciences reflect on objects belonging to World 3. More information on the life and ideas of Popper can be found in Stokes, 1998.

When it comes to the nature of the scientific method, we also want to mention Thomas Kuhn's work (Kuhn, 1962) and his use of the term *paradigm*. A paradigm can be described as "a typical example or pattern of something" (<http://www.merriam-webster.com/>). Yet, when scientists use the word paradigm they mostly have in mind the set of practices that define a scientific discipline at a particular period of time, as proposed by Kuhn. More precisely in *The Structure of Scientific Revolutions* (Kuhn, 1962) he defines scientific paradigms as: "*universally recognized scientific achievements that, for a time, provide model problems and solutions for a community of practitioners.*" Kuhn saw the sciences as going through alternating periods of normal science, when an existing model of reality dominates, and revolution, when the model of reality itself undergoes a sudden drastic change. Paradigms have two aspects. Firstly, within normal science, the term refers to the set of exemplary experiments that are likely to be copied or emulated. (<https://en.wikipedia.org/wiki/Paradigm>). The choice of exemplars is a specific way of viewing reality: this view and the status of "exemplar" are mutually reinforcing. Secondly, underpinning this set of exemplars are shared preconceptions, made prior to (and conditioning) the collection of scientific evidence. In contrast to Popper, results in conflict with the prevailing paradigm (anomalies), are for Kuhn considered to be due to errors on the part of the researcher. It is only when conflicting evidence increases, that a crisis point is reached where a new consensus view is arrived at, generating a paradigm shift.

Popper's ideas can be said to be prescriptive while Kuhn's are more descriptive. Both originated from reflections on the natural sciences. For this reason we mention another model, originating from the social

sciences, proposed by Van der Veer Martens and Goodrum (2006). This model has three types of factors: empirical factors, socio-cognitive factors and theoretical factors. The first and the last type have two aspects each so that there are in total five factors. These are:

applicability – constructivity – accessibility – connectivity – generativity

Concretely, these factors are related to the following questions:

- *Applicability* (the first empirical factor)
 - Does this theory apply to a wide variety of phenomena?
 - How salient are the phenomena? Or stated otherwise: How important are these phenomena?
- *Constructivity* (the second empirical factor)
 - Is this theory constructed so as to facilitate its testing or replication?
- *Accessibility* (the only socio-cognitive factor)
 - How easy is this theory to understand and utilize?
 - How important is it to the discipline as a whole?
 - What types of publication channel have carried it?
 - How else has this theory been communicated?
- *Connectivity* (the first theoretical factor)
 - How does this theory fit into existing theoretical frameworks?
 - How closely is it tied to previous theories?
- *Generativity* (the second theoretical factor)
 - Can this theory generate a new theoretical framework or new uses of earlier theories?

Although presented as a model for theories in the social sciences, we think that its applicability goes beyond the social sciences and hence can be applied to many other fields of investigation.

We note that the term *science* is also used to denote reliable and teachable knowledge about a topic, as in *library and information science*, *computer science* or *public health science*.

Because of increasing pressures and increasing needs for funds, science is, unfortunately, becoming more a race of all against all, instead of a joint human endeavor for the benefit of humanity. Yet, or maybe because of this, scientists form collaborating teams (often international groups) leading to an increase of multiauthored publications. Notwithstanding this caveat, the basic purpose of scientific research is still to benefit the community at large by trying to know the unknown, explore the unexplored and create awareness about new research findings.

2.1.3 Citizen Science

A relative newcomer in the realm of science is the citizen scientist and the terms citizen science or crowd science. This term refers to amateurs or networks of volunteers who participate in a scientific project, usually by collecting or analyzing data. It is a form of public participation in the scientific enterprise. It is said that such participation contributes positively to science-society-policy interactions and is a form of democratization of science. Newer technologies, often computer related, have increased the options for citizen science.

2.1.4 Open Science

Following the footsteps of movements like open source, open science is a movement that aims to make research and research output more accessible. By making data, software and publications openly accessible, researchers can increase the transparency and replicability of their research, both for colleagues and a wider audience. As such, open science and citizen science are related in bringing science to the general public.

2.2 SCIENTIFIC DISCOVERIES

2.2.1 Types of Scientific Discoveries: Koshland's cha-cha-cha Theory

In 2007 the journal *Science* published a posthumous essay in which Koshland, a former editor of *Science*, formulated the cha-cha-cha theory of scientific discovery (Koshland, 2007). Koshland proposed to subdivide scientific discoveries into three categories: charge, challenge and chance, hence the name cha-cha-cha theory.

A discovery belongs to the “Charge” category if the problem is obvious (e.g., cure cancer), but the way to solve it is not clear at all. The discoverer is he or she who sees what everyone else has seen, but thinks what no one else has thought before. A typical example, provided by Koshland, is Newton's discovery and explanation of gravity.

A discovery falls into the “Challenge” category if it is the response to an accumulation of facts or concepts that were unexplained. Often these facts were brought to the fore by individuals referred to as “uncoverers” by Koshland. An example is Einstein's theory of special relativity, a description of the relation between space and time, later extended by the

so-called general relativity theory to include gravity. Einstein was guided to his investigations by the observed inconsistency of Newtonian mechanics with Maxwell's equations of electromagnetism. Hence his theory was a response to some unexplained facts. Solutions to important challenges may lead to paradigm shifts in the sense of Kuhn (1962).

Finally, a discovery may fall into the "Chance" category. Such discoveries are, however, not pure luck but "favor the prepared mind." Chance discoveries may also be said to be the result of a serendipitous finding. A well-known example belonging to this category is Fleming's discovery of penicillin.

Koshland stressed the fact that often the discoverer needs not one but a number of original discoveries until the discovery is complete. He further wrote that the cha-cha-cha theory is not only applicable to big discoveries, but also to small everyday findings. This encouraged us (Rousseau, 2007b) to see whether we could apply the cha-cha-cha theory to some findings in informetrics. We consider the application of an existing theory, concept or tool to a new situation as a "charge" discovery, as it means taking a (small) step that no one else has taken before. Our field is an applied field, hence for this reason most of our field's "discoveries" will fall into the "Charge" group. If someone just collects data and tries to find out which statistical distribution fits best, we consider this a "Chance" discovery, in particular if the resulting distribution turns out to be interesting and is confirmed later.

We next present some examples of discoveries in the information sciences and their corresponding cha-cha-cha category. The topics mentioned in these examples are discussed further on in this book.

- Problem: information retrieval across scientific disciplines;
Discovery: Science Citation Index (SCI) (see Section 5.2);
Discoverer: Garfield (1963);
Category of discovery: charge (as the idea of a citation index existed already).
- Problem: evaluation of journals without the use of (subjective) peer review;
Discovery: the journal impact factor;
Discoverers: Garfield and Sher (1963), but based on ideas by others; see (Archambault & Larivière, 2007);
Category of discovery: charge.
- Problem: finding a simple way for the evaluation of an individual scientist;

- Discovery: the h-index (see Section 7.3);
 Discoverer: Hirsch (2005);
 Category of discovery: charge.
- Problem: finding a regularity in the scattering of scientific knowledge about a topic;
 Discovery: Bradford's law of scattering (see Subsection 9.3.2);
 Discoverer: Bradford (1934);
 Category of discovery: chance (because he was actually searching for a way to compile a complete bibliography).
 - Problem: proving the mathematical equivalence of the bibliometric laws;
 Discovery: a mathematical proof (see Subsection 9.3.2);
 Discoverer: Egghe (1985, 1990, 2005), based on partial work and suggestions of others, such as Fairthorne (1969), Yablonsky (1980), and Bookstein (1976, 1979, 1984);
 Category of discovery: challenge.
 - Problem: explanation of the ubiquity of Lotka's law (power laws);
 Discovery: success-breeds-success (see Subsection 9.3.2);
 Discoverer: de Solla Price (1976);
 Category of discovery: charge, as it was an application of Simon's work (Simon, 1957) and the Yule process (Yule, 1925).
 - Problem: a representation of relations between scientific authors;
 Discovery: author cocitation analysis (see Subsection 5.10.3);
 Discoverers: White and Griffith (1981);
 Category of discovery: charge.
 - Problem: structure of inlinks on the Web
 Discovery: it follows a power law (=Lotka's law);
 Discoverer: Rousseau (1997b, small sample); Michalis, Petros, and Christos Faloutsos (1999, large scale);
 Category of discovery: chance (Rousseau); charge (or chance?) (Faloutsos).

Besides through discoveries, applied fields such as scientometrics make progress through developments such as, e.g., the Social SCI which was developed based on the SCI.

2.2.2 Replication Research

We add a few words on the opposite of scientific discoveries, namely replication research. First we make a distinction between replication and validation studies. A replication study in the proper sense means that one

performs the same investigation, using the same experiments, materials, and tools as the original or one re-analyzes the original data. A validation study has the same purpose as the original, but one may use different data and do similar experiments with the purpose of coming to the same conclusions.

Replication research is not popular at all as it is not original and hence rarely leads to recognition by peers. For an inquisitive mind, it might also be less interesting. Yet, double-checking is an aspect of the scientific method as described by Popper. Normal science as we know it produces new findings. The more sensational, say unexpected or difficult to find, the higher the response inside and even outside the author's field. Yet, many publications are never or rarely cited and hence their content is never thoroughly checked after publication. As long as uncited is the same as unused no harm is done, except in an indirect way as clearly a lot of money may have been wasted. Unfortunately, unreplicable research, especially in the life sciences, is not rare at all (Begley & Ellis, 2012). For instance, scientists at Bayer reported that among 67 projects only 14 matched up with the published findings (Mullard, 2011).

A large-scale replication effort in psychology sought to replicate 100 studies published in reputable psychology journals in 2008 (Open Science Collaboration, 2015). While 97 of the original 100 studies reported statistically significant results, only 36 of the replications yielded significant results. Overall, many replications had far weaker results than the original studies.

Russell (2013) rightly states that reproducibility separates science from anecdote. Consequently, he argues that funding agencies should tie grant funding to replication attempts. He realizes that such a proposal may encounter objections, but provides answers to them. We refer the reader to the original article for more details.

We should mention also that scientometrics struggles with irreproducibility. Glänzel (1996) already warned that scientometric studies should be reproducible, and stressed that this can only happen if all sources, procedures, and techniques are properly documented. He further mentions that validation studies should be designed for detecting systematic errors and estimating random ones. Methodological validation studies must ensure that scientometricians really measure what is intended to be measured.

2.2.3 Shneider's Typology of Scientists

Shneider (2009) distinguishes four stages in scientific research and correspondingly four types of scientists based on the type of work they prefer.

Although in reality most scientists are probably a mixture of the four prototypes, many may prefer one of the four stages and scientific attitudes that go with them.

Shneider's four stages in scientific research.

Stage 1: Introduction of new subject matter, based on a new scientific language and often including new observations and/or experimental results. First stage scientists are not only those who discover new facts, but as stated above, can be among the first to study these new facts.

First stage scientists often need to be somewhat imprecise or inaccurate because not all necessary facts are known or properly understood. At this point the theory often contains uncertainty. Philosophical, aesthetic and cultural views, analogies and literature are instrumental to the first stage scientists' mode of thinking. Such scientists are real scientific pioneers.

Example: The double helix structure of DNA as proposed by Watson and Crick.

Stage 2: Development of major techniques. This includes the re-application of methods previously developed in another discipline (plus rethinking and adjustments to new tasks). The main characteristics of second stage scientists are ingenuity and inventiveness, an ability to implement ideas and a high risk-tolerance. Shneider mentions here that the two most noticeable changes to Newtonian mechanics were introduced by Joseph Lagrange and by William Hamilton. He considers both of them to be great second stage scientists.

Stage 3: Most of the actual data and useful knowledge is generated in stage 3. This includes the re-description of subject matter, creation of new insights and questions. Difficulties and unexplained phenomena often give birth to new first stage work. Most useful personal qualities of third stage scientists are being detail-oriented and hard-working. An extensive knowledge of philosophy or art is not required.

Example: Engineers and scientists such as Heaviside redefining their knowledge in mathematical terms in the 19th and early 20th centuries.

Another example is the work of Samuel Eilenberg and Saunders Mac Lane who introduced category theory as a general framework for all of mathematics.

Stage 4: Communication of knowledge; organization of knowledge.

These scientists write reviews and organize what is known. Without the fourth stage scientists, the explosion of new data generated at the third stage would be chaotic. Their work leads to the

development of (more) applications. Fourth stage scientists use a broad spectrum of cultural and philosophical views. Their work serves to inspire new generations of scientists as they are often writers of influential books. They are not only good in understanding the facts, but are also well-informed and remember great amounts of necessary information which they combine with useful up-to-date scientific results.

Example: Simon Singh (PhD in particle physics) who wrote a book and made a documentary about the proof of Fermat's Last Theorem by Andrew Wiles.

The existence of these types of scientists or this type of work, leads to problems in research evaluation. Indeed: fourth-stage work is easily recognized, although not always appreciated, while "typical" research evaluation is geared towards third-stage research. Yet, it is more difficult to evaluate second-stage research and this becomes extremely challenging for first-stage work. The lack of methods to evaluate first-stage work will probably remain as even peers do not always recognize its potential.

As a consequence of these reflections, Shneider writes that it may happen that the development of a discipline virtually stops and this in any stage (least likely in the first stage). Then too much effort goes into the wrong research direction. Unfortunately, such cases might become self-supporting due to the present organization of the academic system in which people go where money goes, and money goes where people go. This leads to the formation of the scientific analog of economic bubbles. As a result, the number of people working in a field does not accurately reflect its actual promise. This is an important lesson to be remembered, especially by young scientists.

This subsection, and in particular mentioning stage four scientists, leads us to a subsection on scientific communication.

2.2.4 Scientific Communication

The term *scientific communication* refers to all forms of contact between researchers as part of their professional behavior. Scientific communication can be seen as part of a complex social system consisting of formal and informal components. It includes reading and studying manuscripts (published or not), downloading, criticizing (through direct contact, by e-mail, or by letters to the editor), mentoring (younger colleagues) and collaborating. Moreover, communication by scientists includes two other important aspects of the scientific profession: Communication with the

public at large and communication with reviewing authorities, which may have no scientific background, or have only a background in a field totally different from the researcher whose work or working habits are reviewed.

As for scientific communication in journals and similar outlets, we note that already in the 1960s Price (1963) observed an exponential increase in scientific publications. Since then, this tendency has hardly declined. Scientific journals communicate and document the results of research carried out in universities and various other research institutions, serving as an archival record of science. The first scientific journals, *Journal des Sçavans* followed by the *Philosophical Transactions*, began publication in 1665. Since that time, the total number of active periodicals has steadily increased.

2.3 A TWO-TIER PUBLICATION SYSTEM

2.3.1 Types of Publications

We provide a short glossary of types of publications

Publication: what has been published, not necessarily peer-reviewed. Publications may involve a formal publisher or not. We define a formal publisher as a corporate entity or scientific society that produces and distributes something, such as a book or magazine, in printed or electronic form.

Edited book: A collection of chapters written by different authors, gathered and harmonized by one or more editors; conference proceedings are one type of edited books (Ossenblok et al., 2015).

Monograph: A book on a single topic, written by one or more authors.

Textbook or course book: A monograph written mainly for teaching purposes.

Enlightenment literature (popular-science books): Books, often monographs, written for a general audience.

A *scientific article* is a text written for a scholarly audience. It can be published in a scientific journal or as a chapter in an edited book and may describe original research, contain theoretical considerations or an overview of a part of the scientific literature.

A *peer-reviewed article* is an article of which the scientific quality has been checked by other scientists, so-called peers, before publication.

Preprint: This notion originally referred to a text accepted for publication, but nowadays the term preprint is also used for a technical report, a research manuscript or a working paper.

E-print = electronic preprint

Gray literature: The Fourth International Conference on Gray Literature (GL '99 Conference Program, 1999) defined gray literature as follows: “*That which is produced on all levels of government, academics, business and industry in print and electronic formats, but which is not controlled by commercial publishers.*” Working papers, technical reports, theses, preprints, technical handbooks, and government documents are examples of gray literature.

Technical reports are a form of gray literature. A technical report can be described as a document written by a researcher or group of researchers detailing the results of a project, often with the purpose to submit it to the sponsor of that project (based on: <http://libguides.gatech.edu/c.php?g=53991&p=348582>).

Although technical reports are very heterogeneous they tend to possess the following characteristics:

- they are published before the corresponding journal literature, if they end up in the formal literature at all;
- their content contains more technical details and jargon than the corresponding journal literature;
- technical reports are usually not peer reviewed;
- some reports may be classified or offer only restricted access.

Working papers: This is a term mostly used by economists and management scientists to refer to a prepublication version of a manuscript. Their departments often have numbered Working Paper Series. Working papers are generally provided for discussion before they are formally submitted for publication in a journal or an edited book.

In the context of research evaluation, one sometimes makes a distinction between citable publications and others. This distinction refers to the issue of including this publication in the denominator of the calculation of a journal impact factor or not (see Chapter 6: Journal Citation Analysis). As this distinction is made by a commercial database and is, at times, rather ad hoc it is better to make another distinction. White (2001) uses the terminology reference-heavy articles (normal articles, reviews, notes) and reference-light ones (editorials, letters to the editor, meeting abstracts, book reviews). The term “Notes,” referring to short communications of a scientific character, has been removed from Thomson Reuters’ databases in 1997. Besides these, journals also publish errata, retractions, corrections, updates, comments and author replies. Occasionally they may re-publish articles of exceptional importance, often with new comments. Most of these can be considered to be reference-light. Universities and

research institutes sometimes publish advertisements which have the look and feel of real research articles, mostly in highly cited journals like *Nature* and *Science*. Although this is duly mentioned in these journals, this still might lead to confusion among some readers (Chen, 2015). Such advertisements may even get cited.

We like to mention that, contrary to textbooks for undergraduate students, journals are not meant to be repositories of the one and true knowledge (and according to Popper's views, textbooks aren't either). They should better be considered to be discussions amongst experts, who might disagree. Journals are a place where experts can exchange methods, results, opinions, calculations, observations, and the like.

2.3.2 Steps in the Publication Process

Once a researcher or a group of collaborating researchers, decides that they have obtained results that can be considered to form a coherent unit, they may want to make these results public. Most of the time this implies that a text—a first draft—describing their findings is prepared. As the title is the first aspect colleagues may see, statements made in the title should be correctly formulated and supported by the evidence presented in the article. Note that not all scientific results lead to a text: Research findings may also be communicated under other forms such as a computer program, an instrument, or a construction.

This first draft is often presented in an internal seminar. This provides researchers with immediate feedback. Departmental colleagues may also help to overcome challenges faced by researchers whose native language is not English (assuming that publication is intended for an international, English reading, audience). The revised text, referred to as a preprint, is then often put in a preprint archive, a so-called e-print archive or repository (discussed below). Friends and some colleagues, members of an invisible college, see [Section 2.3.6](#), may even receive a version before the text is finished as an e-print, so that they can give early feedback (for which they will be acknowledged in the final version).

The arXiv (<https://arxiv.org>) is the best known repository for electronic preprints of scientific work, mostly covering papers in mathematics, physics, astronomy, computer science, quantitative biology, statistics, and quantitative finance. Yet, also informetric articles are accepted. In many fields of mathematics and physics, almost all scientific papers are self-archived in the arXiv. The arXiv was originally developed by Paul

Ginsparg, starting in August 1991 as a repository for preprints (later called e-prints) in physics and later expanded to include other fields. It was originally hosted at the Los Alamos National Laboratory and called the LANL preprint archive. Its existence has had a huge influence on the open access movement (see further Section 3.2). Nowadays, Cornell University is the main responsible for the arXiv's maintenance. Many other, smaller subject-specific repositories exist. E-LIS (<http://eprints.rclis.org/>), for instance, is a smaller archive for e-prints, postprints and reprints in library and information science. Besides early visibility, e-prints may lead to useful feedback from peers, sometimes even leading to corrections of errors.

The e-print version of a scientific paper is often submitted to a conference and, if accepted for presentation (oral or as poster), leads to more feedback, from a larger group of peers. If the research is not substantive then a version based on conference attendees' feedback may be published in the conference proceedings, ending the publication process.

If research is more substantive then an enlarged and revised version of the conference paper is submitted to a scholarly journal and, if considered within the scope of the journal, the (journal) peer review process is started. Of course, an author may skip one or more of the above stages and submit a manuscript directly for publication in a journal. In a cover letter the corresponding author must declare that the same paper has not been submitted for publication at the same time and that all authors have approved the manuscript and agree with its submission. We note that the corresponding author is that author who takes primary responsibility for communication with the journal during the manuscript submission, peer review, and publication process. They typically ensure that all the journal's administrative requirements are properly completed and submitted. Usually the submission needs some revision (if it is accepted at all) and when this is performed according to the comments of the reviewers and the editor, the article enters the publishing process and will be published (electronically, in print, or in both versions). The final version may or may not be made public for free (see further under Open Access, Section 3.2).

Simplifying the process, one may use the term two-tier communication model. In this model, the first tier consists of communication on the Internet for free (e.g., through publicly available repositories) while the second tier consists of formal publications (Zhao, 2005). The distinction between these two tiers is nowadays less clear, since "gold" open access publications are also freely available on the web.

2.3.3 Structure of a Research Paper and Major Steps Between Submission and Publication

Structure of a Research Article

An article has a title and usually shows its author(s) and address(es) in the byline under the title. This is followed by an abstract and, often, a set of keywords. The main part of the article typically follows the IMRaD structure, where IMRaD stands for Introduction, Methods, Results and Discussion. In some fields, a short literature review is expected, placed between the Introduction and the Methods section, while usually there is also a Conclusion after the Discussion chapter. Then there is room for acknowledgements and finally a reference list, sometimes followed by an appendix and supplementary online material.

Not all articles strictly follow this scheme, but the above is a general guideline. Describing methods should not be confounded with describing the results, while discussions of these results are for the discussion section, which, again, is not the same as stating a conclusion. Note that the main conclusion should also be part of the abstract.

Nowadays this abstract is often required to be a structured abstract. A structured abstract has a fixed structure, consisting of: Purpose, design/-methods/approach, findings, research limitations, implications, value and/or originality. On the one hand, this structure makes searching for information easier, but on the other hand it is obvious that prescribing to follow this structure is counterproductive for articles based on pure logical thinking or which are the result of a serendipitous observation.

Major Steps Between Submission and Publication

When the editorial office receives a submission it is first checked for formal completeness. Does the submission have a title; are authors, their institutes and addresses unambiguously reported; is there a corresponding author; have the roles of the authors been revealed (if this is a requirement); are there references; has supplementary information been submitted? Are figures and formulae clear and readable?

The editor checks if the article falls within the scope of the journal, otherwise it is immediately rejected (a so-called desk rejection, also see the next chapter). Nowadays many editorial offices submit submissions to a plagiarism detection system, before it is sent to one or more reviewers.

When receiving the reviewers' reports, the Editor-in-Chief (in short: EIC) reports their findings to the author(s). For those papers that have to be revised and resubmitted the EIC reviews the changes and checks if all

comments made by the reviewers have been correctly addressed or replies contain convincing arguments against the statements of the reviewers. More details about this step are given in the next chapter where the role of the Editor-in-Chief and of the reviewers is discussed in more detail.

High quality journals used to revise the manuscript for English language and grammar. It is a pity that nowadays this is rarely done anymore, even for submitted monographs. Copy editors implement the journal's manuscript style or check if this has been done by the authors in an appropriate way.

The paper is typeset and proof-read by professional, preferably native English speaking, proof-readers (again it is assumed here that the work is meant for an international audience) who identify any typographical errors and highlight possible inconsistencies. Once this is complete the typeset proofs are sent to the corresponding author(s).

Either all authors receive typeset proofs, so-called galley proofs, from the publisher or the corresponding author makes sure that they do. When all authors agree on the final page-proof the work is ready to be published.

The article receives a DOI (a Digital Object Identifier) a code that uniquely identifies the article. For instance, the publication by Hirsch (2005) has DOI "10.1073/pnas.0507655102" and can be retrieved from <https://doi.org/10.1073/pnas.0507655102>. Nowadays the article is usually published online in a "preview" version. This version is exactly the same as the final version except that volume, issue and page numbers are not yet assigned.

Finally the article is published in a particular issue of a journal's volume and assigned page numbers. If a journal is published only electronically there is no reason to go through this "preview" step and the article is published immediately; it often has no page numbers, just an article number. A similar observation holds for journals that follow an article-based publishing strategy. This means that when accepted an article is immediately published in its final form, including volume, issue and page numbers.

2.3.4 Qualifying for Authorship

Returning to the issue of publishing, we consider the important question: What is an author? We next describe the guidelines as published in

<http://www.icmje.org/recommendations/browse/roles-and-responsibilities/defining-the-role-of-authors-and-contributors.html>. An “author” is generally considered to be someone who has made substantive intellectual contributions to a published study. An author must take responsibility for at least one component of the work, should be able to identify who is responsible for each of the other components, and should be confident in their coauthors’ ability and integrity. In the past, editors and readers were rarely provided with information about the exact contribution of persons listed as authors or mentioned in the acknowledgments section. Nowadays, however, most journals publish information about the contributions of each person named as having participated in a submitted study. Moreover, they may ask for the name of a contributor who will act as a guarantor, this means the person who takes responsibility for the integrity of the work as a whole.

Another problem is the question of the quantity and/or quality of contribution that qualifies for authorship. The International Committee of Medical Journal Editors or ICMJE (<http://www.icmje.org/recommendations/browse/roles-and-responsibilities/defining-the-role-of-authors-and-contributors.html>) recommends the following four points as criteria for authorship:

1. substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data.
2. drafting the article or revising it critically for important intellectual content.
3. final approval of the version to be published.
4. Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Authors should meet each of these four conditions. Acquisition of funding, pure data collection (but see below for a remark on biological field work), or general supervision of the research group alone does not constitute authorship.

All persons designated as authors should qualify for authorship, and all those who qualify should be listed. Authorship of big science investigations such as multicenter trials (in medicine); particle physics studies (as e.g., performed in CERN) or use of space ships or telescopes is often attributed to a group, using a group name such as e.g., the ATLAS collaboration (Aad et al., 2015). Also in cases of mega- (Kretschmer & Rousseau, 2001; Sen, 1997) or hyper-authorship (Cronin, 2001) all members of the group who are named as authors should, in principle,

meet the above criteria for authorship. We think, however, that such groups are in fact a special case and one should leave decisions on authorship to the leaders of such groups instead. Indeed, in such cases membership does not lead to visibility. Some journals demand specific author contribution statements. In such cases information is required about who designed, directed, coordinated, provided conceptual guidance, provided technical guidance, planned, performed experiments, analyzed data, generated and characterized constructs, contributed, provided essential reagents, stem cells, tissues or other body parts (e.g., mice brains), commented on the design of experiments, and wrote documentation.

Davenport and Cronin (2001) proposed a three layer division of authors, depending on their contribution. They made a distinction between core, middle layer and outer layer tasks. This idea was taken up by Danell (2014) in an analysis of author contributions published in *Nature Neuroscience* (2012–2013). [Table 2.2](#) shows this three-tier contribution taxonomy. Of course, the examples shown in [Table 2.2](#) depend on the field. These tasks would mean little to a colleague in the formal sciences, for whom providing a clear and logical chain of thoughts, is a core task.

Obviously the division between core- and middle-layer tasks in a concrete investigation is open for discussion. Core tasks are mainly leadership tasks performed by principal investigators. This implies that often the most important intellectual contribution may come from middle layer authors. Sometimes even collecting data, as in biological field work, may need the most ingenuity. Although outer layer tasks generally do not qualify for authorship according to the ICMJE criteria, Danell (2014)

Table 2.2 A three-tier publication contribution taxonomy

Type of contribution	Examples of tasks
Core task	<ul style="list-style-type: none"> • Conception and design • Writing the manuscript
Middle layer tasks	<ul style="list-style-type: none"> • Conducting experiments • Data analysis • Interpretation of data
Outer layer tasks	<ul style="list-style-type: none"> • Project management • Obtaining funding • Providing samples/data • Providing technical assistance • Collecting data

found 13.8% of outer-layer contributors as coauthors in the papers he investigated.

Referring to the issue of mega-authorship we note that Piternick (1992) already discussed multiple authorship and pointed out an article in high energy physics with 246 authors. In 1993 an article with 972 authors (The GUSTO investigators, 1993) received the Ig Nobel prize for Literature because it had an average of one author per two words. This tendency for ever larger collaborating groups has not stopped as testified by an article published in 2015 describing the size of the Higgs boson (Aad et al., 2015). This article has 5099 authors (our count). Of the 33 pages, 24 contain the author list.

Increasing numbers of coauthors consequently led to an increasing number of related problems such as:

Responsibility of authors for the contents of the manuscript (an ethical problem).

Possible ghost writing (another ethical problem).

Honorary authorship (another ethical problem).

Restrictions on the number of authors listed by a journal (an editorial decision with possible consequences for some authors who become “invisible”).

Appropriateness of using a group name (again making authors invisible).

How to allocate credit for publishing and for receiving citations (a problem related to evaluation, discussed further on in this book).

Contributors Listed in the Acknowledgments

All contributors who do not meet the criteria for authorship should be listed in an acknowledgments section. Examples of such persons are those who provided purely technical help, writing assistance, or a department chairperson who provided only general support. Of course funding and material support should also be acknowledged. If persons are acknowledged they must first give permission that their name is used in such an acknowledgement.

2.3.5 Collaboration

It is well-known that the fraction of articles with more than one author is increasing over the years. Smith (1958) and Price (1963) already observed this phenomenon. The rise in multiple authorship has been confirmed by Weller (2001, p. 121), Lipetz (1999), Schubert (2002) for authors in *Scientometrics* and Behrens and Luksch (2011) in mathematics.

Gordon (1980) proved that the probability of acceptance (of a submission to a journal) increases with the number of authors. Oromaner (1975) found an increasing relation between the number of authors and the number of received citations. Waltman, Tijssen, and van Eck (2011) studied coauthorship in terms of the average geographic distance of their institutes and found that this average has increased considerably over the past 30 years.

Given the rise of collaborative research, voices are raised to abolish the notion of authorship, and to replace it by the notion of contributor, implying a continuum of activities, instead of the notion of author, which implies a yes-no situation, see Rennie and Yank (1998). When supporting this model, colleagues often refer to end credits such as those used in the film industry. These credits list all the people involved in the production of a film, starting with the leading actors, the film director, and followed by the whole crew consisting of editors, writers, stand-ins, photographers, costume designers, set decorators, digital effects computer teams, prop masters, gaffers, and so on.

2.3.6 Invisible Colleges

Groups of colleagues that follow each other's work closely may be said to form a so-called invisible college. Modern use of this term was introduced by Price (1963, 1986). Yet, its original use dates from the 17th century when the Royal Society of London was founded. Members often did not belong to a formal institution and hence referred to themselves as an invisible college, because of their geographic proximity, regular meetings and shared interests (Zuccala, 2006). Price observed that although great artists and researchers are both intensely creative humans, the artist's creation is personal, while the scientist needs recognition by peers. For this reason scientists devised an informal mechanism to stay in (almost) daily contact with a group of peers. According to Price such an invisible college is composed at most of one hundred colleagues. Yet, Price just offered a rather vague description and not a precise definition. Studying the use of the term over the years led Zuccala (2006) to the following definition:

An invisible college is a set of interacting scholars or scientists who share similar research interests concerning a subject specialty, who often produce publications relevant to this subject and who communicate both formally and informally with one another to work towards important goals in the subject.

Note that nowadays geographic proximity plays no role (or maybe just a minor role) in the definition of an invisible college.

2.4 A THREE-TIER EVALUATION SYSTEM

Evaluation as such is discussed in later chapters, but here we already make a few observations. Besides the two-tier communication system—online preprint versions and formal publications, see 2.3.2—one may distinguish a three-tier evaluation system applied within the formal publication tier. This three-tier evaluation system consists of counting publications, counting usage e.g., downloads, and counting received citations. More about scientific evaluations can be found in Chapter 8, Research Evaluation.

2.4.1 Peer Reviewed Publications

Different aspects of publishing have been discussed in the previous sections, yet before documents are published and counted they must usually get past the peer-review-hurdle. Indeed, the oldest evaluation level among the three mentioned in this chapter is the peer review process of submitted journal articles. Nowadays, most journals are peer-reviewed, but some parts may not. Journals such as *Nature* have large sections that do not present original research, but are actually scientific journalism. These sections are written by the journal's editorial office or by paid freelance writers. According to Brown (2004) peer review—in general, not just for journals—can be defined as follows: “Scientific peer review is the evaluation of scientific research findings or proposals for competence, significance and originality, by qualified experts (peers) who research and submit work for publication in the same field.” Peer review also takes place when evaluating grant applications, during promotion or tenure decisions of individual scientists; or when starting, evaluating or closing schools or departments. In the context of scientific publication activities peer review is further discussed in Chapter 3, Publishing in Scientific Journals.

2.4.2 Usage

The term *downloads* is clearly related to the age of electronic publications and as such its use is a relatively young development. Besides article downloads an electronic journal may also monitor article views and keep track of links to each article (Rousseau, 2002b). Of course, also the number of downloads in a repository of e-prints or postprints may be collected. In

the era before electronic journals scientists browsed the contents of newly arrived journals, and if interested in a particular article made a photocopy. Maybe they would actually read the article and use it in their own research. In this series of events downloading of full-text articles can be compared to making a photocopy in the preelectronic days.

Collecting download numbers per journal, let alone per article is not obvious if the interested party is not the owner of the repository or the publisher of the journal. COUNTER, launched in 2002, an agreed international set of standards and protocols governing the recording and exchange of online usage data (<http://www.projectcounter.org>) is a partial solution for this. For more information about COUNTER we refer the reader to Conyers (2006), Davis and Price (2006), and Shepherd (2006). COUNTER is able to provide more and more reliable statistics for librarians and vendors, yet was originally designed to measure the use (views) of databases and certainly not of individual articles.

Based on their data COUNTER proposed a journal usage factor (JUF) for journals, which is nothing but the median number of downloads for articles in that journal during a given period of time. Note that COUNTER initially defined the JUF as an average in analogy of the journal impact factor which is an average number of citations per article (for details we refer to Chapter 6: Journal Citation Analysis). As this is a COUNTER metrics, downloads only refer to COUNTER-compliant online usage.

A report (CIBER Research Ltd., 2011) found no evidence that usage (as measured by an average) and citation impact metrics are statistically associated. The authors note that this is hardly surprising since author and reader populations are not necessarily the same. This is in particular the case for journals which have practitioners or students as their main readership. A similar remark about the relationship between downloads and citations was made by Davis (2011). As a result, the usage factor or other usage statistics add new evidence to our understanding of the structure and dynamics of the use of the scientific literature. It also opens up the possibility of developing new ways of looking at scholarly communication, with different journals occupying very different niches within a complex ecosystem. Some colleagues, however, claim that article downloads retrieved shortly after publication can predict future citations, but their strength of prediction is relatively low (Kurtz et al., 2005a,b; Schlögl & Gorraiz, 2010).

Knowing the number of downloads of articles published in a publisher's journals is of interest for the publisher as a means to evaluate the impact (mostly immediate impact) of its journals. Also downloads of e-prints in repositories are of interest for authors and publishers alike.

Indeed, the higher the visibility of articles, the higher the visibility of the journals in which the articles will be published. This is the main reason why (most) publishers allow this kind of prepublication. More about this and the relation with open access (see also next chapter) can be found e.g., in: Antelman (2004), Kurtz et al. (2005a,b), Brody, Harnad, and Carr (2006), Eysenbach (2006), Zhang (2006), Craig, Plume, McVeigh, Pringle, and Amin (2007), Kim (2011), Xia, Myers, and Wilhoite (2011), and Solomon and Björk (2012a,b). On the following site the reader may find what is allowed regarding prepublication and what is not: <http://www.sherpa.ac.uk/romeo/> (organized per publisher).

It should be made clear that downloads (as an indication of usage) do not lead to visibility measurements comparable with citation results. For more on this we refer the reader to Bollen, Van de Sompel, Smith, and Luce (2005). An important point is that downloads are not influenced by delays in publication (of the citing articles). The first measures general interest in a particular new piece of knowledge; the second measures the incorporation of this knowledge into a new document. Most article downloads take place within the first months after publication (CIBER, 2011; Wan et al., 2010). Indeed, aging curves (see Chapter 9: The Informetric Laws) based on citations and on downloads have a different distribution over time. We finally recall that most altmetric indicators include a usage aspect.

2.4.3 Citation Analysis

With the advent of the SCI in 1963 (Garfield, 1963) a new evaluation level, based on received citations, came into existence. Of course, since the 19th Century it has become customary to refer to older work on which a publication was based. It was Eugene Garfield who realized the importance of these references, first as a tool for information retrieval via so-called: “citation pearl growing” or “citation cycling” and as a help for writing the history of a field or topic. However, Garfield and others soon realized that such a citation index could also be used as a tool for research evaluation. In its simplest form the idea was that the more citations received, the better the research. Such an approach is, of course, extremely naïve. Details about the proper use of a citation index for evaluation purposes are given in Chapter 8, Research Evaluation.

Citation indexes such as Scopus, the SCI, the Social Science Citation Index (SSCI), the Arts & Humanities Citation Index (A&HCI) and the Book Citation Index (BCI) and their availability on the Internet are discussed in Chapter 5, Publication and Citation Analysis.