How do I write a scientific article?—A personal perspective

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Abstract: Scientific writing is not an easy task. Although there is no single and universally agreed strategy for assembling a successful scientific article, it is undeniable that some basic notions, gathered after decades of experience, may help increasing the chance of acceptance of a scientific manuscript. Therefore, the purpose of this article is to present a personal and arbitrary perspective on how to write a scientific article, entailing a tentative flowchart and a checklist describing the most important aspects characterizing each section of the manuscript. The final suggestion, which can be summarized in one simple and straightforward concept, is that you should always remember that a scientific article is meant to be read by others (i.e., referees and readers) and not by yourself.

Keywords: Scientific writing; science; article; publication; publishing

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The main drivers of scientific publishing

The goals of scientific or academic writing, which is conventionally defined as a subcategory of publishing aimed at disseminating academic research and scholarship, are many and multifaceted. First of all, the publication of a scientific article is the mainstay for propagating scientific knowledge, by means of a (usually rigorous) peer-review process that is intended to define validity, quality and originality of the study. In the scientists' perspective, scientific writing is one of the most important criteria for obtaining funds and enabling career progression, since the leading science metrics—Hirsh index (H-index), total impact factor (IF) and number of citations—are based on the number and quality of published articles (1). The capacity to efficiently conveying research findings is hence essential for success in science and medicine (2). More or less consciously, some scientists may also suffer from an obsessive-compulsory (OC) disorder, which makes their life entirely centered around scientific publishing (3). Last but not least, scientific writing contributes to benchmarking (and so defining the ranking of) universities and other scientific institutions (4).

Although medical and scientific writing has evolved for more than a millennium to present times, the publication of the first ever good practices can be probably dated back to the 14th century (5). Nearly three centuries later, in 1667, the English churchman Thomas Sprat first outlined the foremost concept that literary and scientific writing are not comparable, inasmuch as the latter style should be based on plain, accurate, clear and concise text composition rather than using the rhetorical flourishes characterizing literary language (5). Since then, structuring and writing of medical and scientific information has further evolved in parallel with the progress of science, language and types of media used for delivering scientific information (books, journals, newsletter, e-publishing, websites).

Scientific writing is not an easy task. With the obvious premise that there are no validated or universally agreed criteria set to define how a good scientific article should be assembled, and that each scientist often adopts a personal style to deliver academic research, the purpose of this article is to present a personal and arbitrary perspective on how a scientific article should be written, accumulated after a 25-year experience in scientific writing (6).

Getting started

According to my personal perspective, a good scientific

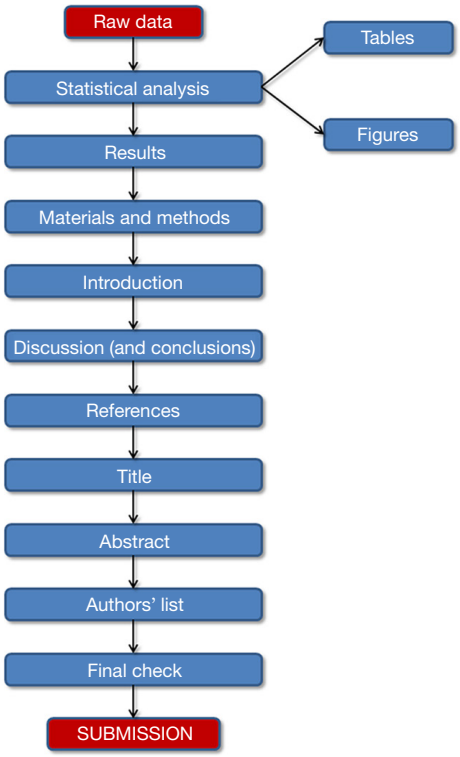

Figure 1 Personal flowchart for writing scientific articles.

article should always begin from accurate analysis of experimental data. Therefore, I always start with a comprehensive statistical analysis, occasionally performing statistics that will not be included in the final article for reasons of space or redundancy. As extensively described elsewhere (7), there are several important statistical aspects that should be considered, such as the analysis of values distribution (i.e., Gaussian, non-Gaussian, skewed), the use of appropriate tests (suited to either continuous or categorical values) for establishing differences between measures obtained in different populations or patients' cohort, the correlation between measured variables (both univariate and multivariate) and—eventually—the impact of measured variables on health risks (i.e., odds or hazard ratios). When the study is centered on diagnostic techniques and/or biomarkers validation, receiver operating characteristics (ROC) curve analysis, diagnostic sensitivity and specificity, negative and positive predictive values, and diagnostic odds ratio should be generally shown. It may also be useful to calculate the "number needed to test" (NNT), i.e., the number of cases that should be measured for identifying one additional adverse outcome. Whenever feasible, diagnostic studies should be arranged around the Standards for Reporting of Diagnostic Accuracy Studies (STARD) guidelines (8,9). Tables and figures may be composed at this stage, bearing in mind that appearance counts. Therefore, they should be self-explanatory, clear and easy to read (i.e., the font size should not be too small).

The "results" section

After statistical analysis has been completed, I usually continue composing the "results" section, along with tables and figures (*Figure 1*). This may enable to obtain a clear picture of results and of the entire work, acknowledging the most important findings, the strengths and the potential drawbacks, already at this stage. Do not include excessive or unnecessary data in this section, which may divert attention from the most significant findings. Some journals offer the interesting opportunity to publish supplementary materials. As a rule of thumb, data contained in a table should not be replicated in a figure, and vice versa, and should be presented in objective means. When presenting data already shown in tables and figures, it may be advisable to use sentences like "*a significant difference was found… as shown in the table (or figure)*". The level of statistical significance should always be indicated (e.g., expressions like "P=ns" or "P<0.05" are discouraged), so that the readers can clearly acknowledge the relevance of your findings. Obviously, "P<0.05" can be either P=0.049 or $P=49\times10^{-3}$, which do not have the same impact. All measures should be given in International System of Units (SI) or SI-derived units, as for journal's style, and must be absolutely coherent throughout the manuscript (for example, it is extremely annoying, even confusing, to read articles presenting values of the same parameter in "g/L", "mg/dL", "mmol/L" throughout the manuscript).

Materials and methods

Once results have been written, I usually draft the "materials and methods" section. Although being often underestimated, this is an essential part of the article. The description of the study population, study protocol and methods may help identifying potential weakness in your research, so setting up the remaining parts of the article accordingly. The description of the study population should be comprehensive, thus including sample size, the most important clinical features that have been recorded, as well as potential confounders (i.e., comorbidities, therapies). Do not forget that the ratio between sample size and

epidemiologic burden of disease is not meaningless; a study based on measuring glucose in 20 diabetic patients is very unlikely to be published in high IF journals. The description of methods should be exhaustive, so including details about the analytical technique, instrumentation, manufacturers, along with the analytical performance of the assays (e.g., functional sensitivity, imprecision and linearity) (10). This aspect is especially important, because it seldom happens to peer-review articles presenting meaningless values, below the functional sensitivity of the assay, or with differences among patients' cohorts that are lower than the imprecision of the method. Always remember that, as for ethics in scientific publishing, your article should contain all the necessary information for allowing replication by others. The statistical tests used in the article should be clearly described here, along with details about informed consent and ethical approval, when applicable. Do not present results in this section. A common mistake, for example, is describing here the study population (i.e., using sentences like "*the final study population consisted of*"), whereas this information must be placed in the "results" section.

The introduction: the challenge grows

Upon completing the previous two sections (i.e., "results" and "materials and methods"), the challenge moves to "introduction" and "discussion". Even in such case, there is no one approach better than another, but I usually find more helpful to start with the introduction. In such way, the ensuing discussion of data is often based on a clearer knowledge of the problem you are dealing with. According to my perspective, the introduction should be constructed defining the main aspects of the biological/clinical/laboratory setting, thus including the definition of biological pathways or diseases, the epidemiology, the significance (biological, clinical, social, economic), the frequency of the most likely outcomes (i.e., favorable evolution, recurrence, mortality). The more importance you can deliver on a certain biological or medical aspect, the more likely is to obtain a positive feedback by the referees. Remember also that the readers (and the referees) are not always clinicians, especially if you are willing to publish your article in a translational science or laboratory medicine journal. Therefore, they may somehow struggle to understand the clinical setting, when this is not sufficiently depicted by the authors.

It is not essential, if not unsuitable, to describe previous studies about the same topic in the introduction. The rather spontaneous question that that comes to the mind of the referees when reading an introduction presenting a huge amount of previous data on the same topic is "*why have you performed another study, if there is so much already published?*". A reliable approach here, is to generate doubts in whom is reading the manuscript, that previous findings may be contradicted, that the same work can be done better or using a larger sample size, or even that no definitive evidence exists on the topic, so that further work is justified. When supported by data, sentences like "*little is known*", "*there is still controversy*" or "*no definitive evidence has been published*" may help. Remember to only include material directly related to the topic of your research in this section. It often happens to read papers with very long introductions, that have little to do with the rest of the manuscript. The introduction should be usually concluded with a clear statement about the aim(s) of the study (e.g., "*therefore, the aim of this study was…*").

Discussion and conclusions

These sections are probably the most important throughout the entire article, since they are meant to deliver the significance of study findings for science, medicine and healthcare in general.

When discussing your findings in this section of the article, raw data should not be repeated, but a remind may be necessary. For example, in the case that a biomarker value in cases and controls was "15 versus 5 mg/L", it may be advisable to use concise sentences like "*the biomarker concentration was found to be 3-fold higher in cases than in controls*", rather than repeating the values.

Data should then be discussed at the light of current knowledge and existing literature. It may be advisable to present here previous findings, after an accurate and comprehensive literature search, so enabling the readers (and the referees) to clearly understand how the actual findings may help improving the knowledge about a specific topic. Irrespective of the possibility that data may be innovative, may contradict or confirm previous findings (bear in mind that the last aspect is often less likely to be well received by the referees), it is always essential to highlight the major strengths setting the work apart from currently available literature. Be very cautious about your conclusions. Biology, and medicine are not exact sciences; it is extremely unpleasant to publish resolute conclusions, that are then contradicted by different findings in ensuing studies. It may hence be advisable to rephrase the final statements with precautious verbs, such as "appear" or "seem", especially when significance and

confidence in your findings are not so strong.

A simple comparison between personal and previously published data may be a good starting point, but is frequently insufficient for article success. For example, if you have discovered a new gene or a new candidate biomarker in the setting of a specific clinical condition or biological pathway, then a tentative pathophysiological explanation should accompany the findings. The simple description of a given phenomenon is always less pervasive than its interpretation according to animal or human biology. Just think at the Scottish biologist Alexander Fleming who casually discovering penicillin in 1928, a finding that has revolutionized medicine. The publication of this "accidental" finding (as literally described by Fleming) in the Bulletin of the World Health Organization in 1929 was not limited to describing that staphylococcal bacteria were dying in proximity to mould colonies contaminating a Petri dish, but he put forward the hypothesis that *Penicillium* in culture may produce an antibiotic substance (i.e., penicillin) which could powerfully inhibit the growth of many bacterial species (11). That clear description has made the fortune of Fleming and mankind, paving the way to saving billions lives worldwide. The biological interpretation of data is especially important when findings significantly deviate from those previously obtained by other authors, so that a reliable explanation should be provided for explaining the difference.

The discussion of the study limitations is an open issue. Some journals envisage a specific part of the discussion, usually before the conclusions, where the main drawbacks of the study should be described. In this case, there is not much to choose. Conversely, when this is not mandatory, I personally prefer to partially avert this part, or only add a vague sentence like "*further studies are need…*". The potential weakness in the study will likely be captured by the referees and, therefore, the most significant limitations can be introduced upon article revision. I actually consider quite masochistic to submit an article with an entire page of limitations, since this would seem an unconscious appeal to the referees to reject your paper. This is not cheating, this is exactly leaving the referees doing their job.

The references

Although the quality of the process of including citations and references is often underestimated, the sources of information delivered in the text should always be cited. For example, it is unacceptable to read sentences like "*it is known that*" or "*it has been previously demonstrated that*" without an accompanying citation. Exactly for the same reason, when the description of a certain biological or clinical aspect is given, this should be associated with evidence that you are not delusional, nor that you are trying to cheat providing untrusty information just to support your findings.

The citations to the references in the main body should be prepared exactly as indicated by the instructions to the authors of the journal, and always following the same style. Alternation of citations within round or square brackets, in line with the text or superscripted, is not acceptable. The list of citations should contain the most informative material about the topic. A limited number of self-citations may be helpful to persuade the referees and the readers that you are not really new (or inexpert) about the topic, but a huge number of self-citations should be avoided. Being self-referential is not formally accepted in science and medicine, even if you are a Nobel Prize. Accurately check whether the journal to which you are aiming to submit the article has published similar or overlapping material in recent past. It should be fair (and wise) to add and discuss these articles in your paper and add citations to the references list. The titles of cited journals should be abbreviated as clearly indicated by the instructions to the authors of the journal, and the authors list should also fulfill journal's criteria.

The title

Preparing a good title is critical, since it should actually reflect the findings of the study. Do not use vague sentences such as "*analysis of glucose in diabetes*", since this is not expected to capture a substantial interest from referees and readers, overwhelmed by the million publications available in scientific databases. The use of succinct but clear statements, such as "*glucose is increased in diabetics*", is very likely to capture more interest on the article.

The abstract

The abstract is typically the last part of the manuscript to be written, since it may also be a kind of "collage" of text already written in other parts of the article. It may be advisable to rephrase these parts (e.g., reediting the sentences or changing some words), but the concepts will obviously remain the same. The length and style must be strictly coherent with word count specifications and journal's instructions. Notably, exceeding the word count almost inevitably results in the manuscript being returned to the authors. Avoid writing abstracts with lengthy

"background", and preferably use the text to focus on results and conclusions. If occasionally happens to read abstracts with 50% of text devoted to the background and only 2–4 lines in which results and conclusion are summarized.

The list of authors

The International Committee of Medical Journals Editors (ICMJE) has established four essential criteria according to which the authorship can be credited. These include: (I) substantial contributions to conception or design of the study; or the acquisition, analysis, or interpretation of data for the study; and (II) drafting the article or revising it critically for important intellectual content; and (III) finally approving the version of the article to be submitted; and (IV) agreement to be accountable for all aspects of the study in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved (12). There is no exemption to these rules, and each author should be aware that any deviation should be interpreted as ethical misconduct. Unfortunately, the real life is often different from the idealized picture. There is a nice story on the internet, which gives a funny—but seldom realistic—interpretation of who deserves credit, as well as his/her position in the list of authors, within a scientific article. According to this tale, the first author is a senior graduate student who made the figures, the second author is a grant student who has nothing to do with the project but was included because he/she hang around group meetings usually bringing food, the third author is a first year student who actually performed all the experiments, the statistical analysis and wrote the entire article (and still thinks that being third is "fair"), the middle authors are undergraduate students and technical staff, the penultimate author is an ambitious assistant professor who instigated the paper, whereas the last author is the head of the laboratory, who has not even read the paper but… he is the boss, he got the funding and his name is so famous that the article will hardly be rejected. Besides this funny joke, the ICMJE criteria are and will remain for long the cornerstones for establishing who ultimately deserves to be credited in the paper, in the acknowledgements, or not included in the article. Although there are no written rules about the positions in the authors' list, I have always thought that the scientist who has written the greatest part of (or the entire) article should always be first, the scientist who has thoughtfully revised (and hopefully improved) the article should be last, whereas all the other scientists should be placed in the middle of the author list, according to their actual contribution. Some journals specifically require to list authors' contributions at the beginning or at the end of the article. This section should hence be prepared ethically and fairly; no credit should be given to authors who have not really contributed to a certain activity.

How should I write?

Writing in a good English, considering that the vast majority of scientific articles are published in this langue, is often an insurmountable barrier for both English native and non-English native speakers, but the challenge is obviously magnified for the latter category of scientists. Even the best work, presenting highly innovative or outstanding findings, may finally be rejected if it cannot be fully understood by the referees. As for other human activities, good writing is always a compromise between innate skills and practice. A quite common custom is to have the article revised by the so-called English "teachers". This not always works since, as discussed below, scientific and literary languages are not alike, scientific terminology is unique and often carries specific meanings. I have no personal experience on professional bioscience writers, since I have never used their help. Nevertheless, they can offer various services, such as full-text translation or revision, comments about improving the article before submission, selection of the most suitable journal to submit the work, artwork preparation, help for revising or resubmitting the article (13). Some of these services are now also offered by some scientific journals, but a number of shortcomings are apparent. First, all these services do not come for free. Then, professional science writers are not necessarily expert of one certain subject, so that they may misinterpret some key concepts of the article. Notably, the boundaries between professional medical writing, "guest writing" (writing an article for someone else) and "ghostwriting" (i.e., writing an article but hiring authorship credited to another person) are not so clearly defined, so that some journals are no longer accepting submission prepared by professional science writers (14). Consider also that scientific writers can be legitimate contributors to the article but, according to the criteria of the ICMJE, their contribution must be recognized. Importantly, the long-standing practice of copying and pasting text from other articles is considered as a misconduct (i.e., plagiarism), and can now be easily detected by Editors and publishers using dedicated software programs (15).

As previously discussed, data should not be repeated

multiple times throughout results, discussion, conclusion, tables and figures. Redundant information not only increase the production costs for the publishers (each printed page has a considerable price), but may also antagonize the referees, who may be forced to read the same aspects many (and unnecessary) times. Full results should always be presented once (decided where, among tables, figures or results section).

Another aspect that should be clearly acknowledged is that scientific writing is not like writing a literary piece. The style and construction of sentences may be quite different. When a scientist reads an article, he/she wants to get clear messages, with no flowery prose. Therefore, long, intricate and pompous sentences should always be avoided. Each sentence should have a clearly identifiable subject, a verb and a succinct description of the outcome. It should be no longer than 1–2 lines. It occasionally happens to see papers with very long sentences (i.e., 5–6 lines), so that you no longer remember which is the subject when you get to the end or you need to read the sentence 2–3 times before connecting the subject (usually at the beginning of the sentence) with the verb (at the end of the sentence). The verb should always be placed close to the subject, the "core" of the sentence should be preferably moved to the end, whilst passive verbs should be avoided.

The form, grammar and spelling should be accurately checked (many times, even by different authors) and the use of informal style (e.g., "*haven't*" should be "*have not*", "*wasn't*" should be "*was not*", etc.) or slang and colloquial speech should be limited. I do not personally like using characters like "!" or open questions [i.e., placing a question mark ("?") at the end of a sentence]. The use of adverbs and adjectives may be a good means for highlighting, emphasizing or reinforcing important issues. For example, writing "*we found a difference*" is not the same as writing "*we found a considerable difference*", provided that the difference is really noteworthy.

The final layout

The editor and the referees are often convinced that negligence in the format of the article actually reflects negligence in the research. Their judgment about the quality of the article may hence be unwittingly biased. Therefore, the format should be accurate, in line with the instructions of the authors of the journal. This may also prevent delay in the editorial process, since some journals return the paper to the authors when the instructions are not carefully followed. The type and size of the font is often indicated by the instructions to the authors of the journal. However, when this information is unavailable, a clear font such as "Times New Roman", "Arial", "Calibri" or "Book Antiqua" is preferable. Avoid using different fonts, and especially different sizes (usually a 12-point font size is preferable). Use double spacing and margins of 2–3 cm throughout the manuscript. It often happens to receive papers with single spacing and narrow margins, which are very difficult to read.

The paper should be actually organized as specifically indicated by the instructions to the authors of the journal. Typically, most journals need that the main text of full-length articles be divided into 5–6 sections, i.e., "introduction", "materials and methods", "results", "discussion" (and/or "conclusions") and "references". When different specifications are given (e.g., some journals place the section "materials and methods" at the end of the paper), these should be fulfilled. Carefully avoid to mix up material among the different sections of the article.

As a general rule, the paragraphs should be uniform throughout the article (either aligned or not), and they should all be indented or not indented (according to the instructions to the authors of the journal). The abbreviations should always be spelled. One major issue that challenges the referees is trying to understand what an acronym actually means (e.g., "HF" may stand for "heart failure", but also for "hydrogen fluoride", "hip fracture", "hemorrhagic fever", "high frequency", etc.). Tables, figures and supplementary material should accompany the manuscript as indicated by the instructions to the authors of the journal. Therefore, they should not be included in the main document when this is not expressly requested by the journal.

As a general rule, read the article not less than 2–3 times before submission, or having it carefully read by one or more coauthors. In particular, check multiple times the grammar and the style. It is quite annoying to read papers with no space between a full stop or a comma and the following word. I usually have a final pass on the article on separate days, when the mind is fresh. You can read the article for up to 10 consecutive times without findings errors or typos, but it is very likely that you will catch them on another day. Do not rush to submit. One day more will not have such a bad impact on history of science and destiny of your career.

Selecting the journal and submitting the paper

The final and almost unavoidable activities are selecting the most appropriate journal and then submitting the

Table 1 Checklist describing of the most important aspects characterizing each section of a scientific article

Section	Main issues
Title	Do not use vague sentences and be concise
	Summarize the findings of your study in the title
Authors' list	Follow ICMJE criteria
Abstract	Can be a collage of text written in other parts of the manuscript
	Focus on results and conclusions
	Be coherent with word count specifications and journal's instructions
Introduction	Define the main aspects of the clinical problem
	Explain the main reasons for performing the study
Methods	Comprehensively describe the study population
	Thoughtful description of analytical techniques
	List all statistical tests
	Report informed consent and ethical approval
	Avoid presenting results in this section
Results	Describe only relevant findings
	Do not replicate data of tables and figures
	Include the level of statistical significance
	Use always the same measure unit (preferably SI or SI-derived)
Discussion	Do not report data previously shown
	Discuss findings as for current knowledge and existing literature
	Try to provide biological explanations for your findings
	Do not write resolute conclusions
	List some study limitations, when necessary
References	Always cite the source of your statements
	Use a uniform style for citations, according to journal's guidelines
	Do not use many self-citations
	List previous material published in the same journal
Final layout	Remember that scientific writing is quite different from literary language
	Avoid flowery prose and burdensome complexity
	Avoid long sentences and passive verbs
	Place the verb close to the subject
	Do not use informal style, slang or colloquial speech
	Use adjectives and adverbs to highlight or emphasize important issues
	Be ordered and avoid negligence
	Uniform font type and size
	Uniform text format
	Divide sections as indicated by journal's instructions
	Describe all abbreviations upon first appearance
	Check multiple times grammar and style
	Read the article many times, preferably on different days
Journal selection	Check aims and scope of the journal
	Decide according to sample size and significance of findings
	Analyze the "impact" of the journal
	Verify policy and costs of publication
	Check the types of articles
	Avoid "predatory" journals

ICMJE, International Committee of Medical Journals Editors; SI, International System of Units.

article (16). As for my personal experience, the selection of the target journal can be already made after writing the sections "results" and "materials and methods", since the information therein contained may be sufficient to identify the audience and should hence guide the composition of the remaining parts of the manuscript. There are at least five main criteria driving the choice of one journal over another: (I) aims and scope of the journal (some journals that have previously published similar material can often be found in your references list); (II) sample size and significance of the findings; (III) journal impact (e.g., indexing, IF, visibility, scientific reputation); (VI) policy and costs of publication (open-access; pay for submitting or publishing); and (V) article types (e.g., some journals publish "Brief communications", "technical brief", "technical reports", "research letters" or similar types of papers that are more suited for studies with limited sample size, preliminary or only confirmatory data). The clinical significance of results should not be either oversized or underestimated. This would enable to reduce the overall number of unfavorable revision outcomes and shorten the time to publication. Carefully avoid to submit your article to the so-called "predatory" journals, i.e., financial profit entities based on article processing charges, which do not meet scholarly publishing standards (17). Scientific articles published by predatory publishers will be actually meaningless for your curriculum, since these journals will never be indexed, will never get an IF and, even more importantly, they may suddenly disappear shortly after the publication of your article.

Conclusions

As for the earliest premise, that there is no single and validated approach to write a successful scientific article (18), it is undeniable that some basic notions gathered after years of experience may help increasing the chance of acceptance (*Table 1*). To put it

simply, all the previous concepts can be summarized in one really simple and straightforward concept. A scientific article is meant to be read by others (i.e., referees and readers) and not by yourself. Seems apparently paradoxical, but readers do not just read, but also interpret what they read. These seemingly obvious notions are often overlooked by many scientists, who follow a fairly hedonistic approach in what they write, which may ultimately bother the referees and disappoint the readers.

I really hope that some of the concepts expressed in this dissertation may be a guide or a help, especially for young scientists, who frequently struggle with scientific writing.

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Footnote

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