

## CHAPTER 11

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# How to Write the Materials and Methods Section

*The greatest invention of the nineteenth century was the invention of the method of invention.*

—A. N. Whitehead

### PURPOSE OF THE SECTION

In the first section of the paper, the introduction, you should have stated the methodology employed in the study. If necessary, you also defended the reasons for your choice of a particular method over competing methods.

Now, in “Materials and Methods” (also designated in some cases by other names, such as “Experimental Procedures”), you must give the full details. Most of this section should be written in the past tense. The main purpose of the materials and methods section is to describe (and if necessary, defend) the experimental design and then provide enough detail so that a competent worker can repeat the experiments. Other purposes include providing information that will let readers judge the appropriateness of the experimental methods (and thus the probable validity of the findings) and that will permit assessment of the extent to which the results can be generalized. Many (probably most) readers of your paper will skip this section, because they already know from the introduction the general methods you used, and they probably have no interest in the experimental detail. However, careful writing of this section is critically important because the cornerstone of the scientific method requires that your results, to be of scientific merit, must be reproducible; and, for the results to be adjudged reproducible, you must provide the basis for repetition of the experiments by

others. That experiments are unlikely to be reproduced is beside the point; the potential for reproducing the same or similar results must exist, or your paper does not represent good science.

When your paper is subjected to peer review, a good reviewer will read the materials and methods section carefully. If there is serious doubt that your experiments could be repeated, the reviewer will recommend rejection of your manuscript no matter how awe-inspiring your results.

## MATERIALS

For materials, include the exact technical specifications, quantities, and source or method of preparation. Sometimes it is even necessary to list pertinent chemical and physical properties of the reagents used. In general, avoid the use of trade names; use of generic or chemical names is usually preferred. This approach avoids the advertising inherent in the trade name. Besides, the non-proprietary name is likely to be known throughout the world, whereas the proprietary name may be known only in the country of origin. However, if there are known differences among proprietary products, and if these differences might be critical, then use of the trade name, plus the name of the manufacturer, is essential. When using trade names, which are usually registered trademarks, capitalize them (Teflon, for example) to distinguish them from generic names. Normally, the generic description should immediately follow the trademark; for example, one would refer to Kleenex facial tissues. In general, it is not necessary to include trademark symbols (such as ® and ™). However, some journals ask authors to do so.

Experimental animals, plants, and micro-organisms should be identified accurately, usually by genus, species, and strain designations. Sources should be listed and special characteristics (age, sex, and genetic and physiological status) described. If human subjects were used, the criteria for selection should be described, and an “informed consent” statement should be included in the manuscript. Likewise, if human or animal subjects were used, approval by the appropriate committee should be noted.

Because the value of your paper (and your reputation) can be damaged if your results are not reproducible, you must describe research materials with great care. Examine the instructions to authors of the journal to which you plan to submit the manuscript, because important specifics are often detailed there. Below is a carefully worded statement applying to cell lines and reagents. It is taken from the information for authors of *In Vitro Cellular & Developmental Biology—Animal* (known for short as *In Vitro Animal*), a journal of the Society for In Vitro Biology.

The source of cells utilized, species, sex, strain, race, age of donor, and whether primary or established should be clearly indicated. The name, city, and state or country of the source of reagents should be stated within parentheses when first cited. Specific tests used for verification of cell lines and novel reagents should be identified. Specific tests for the presence of mycoplasma contamination of cell lines are recommended. If these tests were not performed, this fact should be clearly stated. Other data relating to unique biological, biochemical, and/or immunological markers should also be included if available. Publication of results in *In Vitro Animal* is based on the principle that results must be verifiable. Authors are expected to make unique reagents available to qualified investigators. Authors deriving or using cell lines are encouraged to follow the UKCCCR [United Kingdom Coordinating Committee on Cancer Research] Guidelines for the Use of Cell Lines in Cancer Research in respect to validation of identity and infection-free cultures.

## **METHODS**

For methods the usual order of presentation is chronological. Obviously, however, related methods should be described together, and straight chronological order cannot always be followed. For example, even if a particular assay was not done until late in the research, the assay method should be described along with the other assay methods, not by itself in a later part of the materials and methods section.

## **HEADINGS**

The materials and methods section often has subheadings. To see whether subheadings would indeed be suitable—and, if so, what types are likely to be appropriate—look at analogous papers in your target journal. When possible, construct subheadings that “match” those to be used in the results section. The writing of both sections will be easier if you strive for internal consistency, and the reader will be able to grasp quickly the relationship of a particular method to the related results.

## **MEASUREMENTS AND ANALYSIS**

Be precise. Methods are similar to cookbook recipes. If a reaction mixture was heated, give the temperature. Questions such as “how” and “how much” should

be precisely answered by the author and not left for the reviewer or the reader to puzzle over.

Statistical analyses are often necessary, but your paper should emphasize the data, not the statistics. Generally, a lengthy description of statistical methods indicates that the writer has recently acquired this information and believes that the readers need similar enlightenment. Ordinary statistical methods generally should be used without comment; advanced or unusual methods may require a literature citation. In some fields, statistical methods or statistical software customarily is identified at the end of the materials and methods section.

And again, be careful of your syntax. A recent manuscript described what could be called a disappearing method. The author stated, "The radioactivity in the tRNA region was determined by the trichloroacetic acid-soluble method of Britten et al." And then there is the painful method: "After standing in boiling water for an hour, examine the flask."

## NEED FOR REFERENCES

In describing the methods of the investigations, you should give (or direct readers to) sufficient details so that a competent worker could repeat the experiments. If your method is new (unpublished), you must provide *all* of the needed detail. If, however, the method has been published in a journal, the literature reference should be given. For a method well known to readers, only the literature reference is needed. For a method with which readers might not be familiar, a few words of description tend to be worth adding, especially if the journal in which the method was described might not be readily accessible.

If several alternative methods are commonly employed, it is useful to identify your method briefly as well as to cite the reference. For example, it is better to state "cells were broken by ultrasonic treatment as previously described (9)" than to state "cells were broken as previously described (9)."

## TABLES AND FIGURES

When many microbial strains or mutants are used in a study, prepare strain tables identifying the source and properties of mutants, bacteriophages, plasmids, etc. The properties of multiple chemical compounds can also be presented in tabular form, often to the benefit of both the author and the reader. Tables can be used for other such types of information.

A method, strain, or the like used in only one of several experiments reported in the paper can sometimes be described in the results section. If the description

is brief enough, it may be included in a table footnote or figure legend if the journal allows.

Figures also can aid in presenting methods. Examples include flow charts of experimental protocols and diagrams of experimental apparatus.

## **CORRECT FORM AND GRAMMAR**

Do *not* make the common error of including some of the results in this section. There is only one rule for a properly written materials and methods section: Enough information must be given so that the experiments could be reproduced by a competent colleague.

A good test, by the way (and a good way to avoid rejection of your manuscript), is to give a copy of your finished manuscript to a colleague and ask if he or she can follow the methodology. It is quite possible that in reading about your materials and methods, your colleague will pick up a glaring error that you missed simply because you were too close to the work. For example, you might have described your distillation apparatus, procedure, and products with infinite care—but then neglected to define the starting material or to state the distillation temperature.

Mistakes in grammar and punctuation are not always serious; the meaning of general concepts, as expressed in the introduction and discussion, can often survive a bit of linguistic mayhem. In materials and methods, however, exact and specific items are being dealt with and precise use of English is a must. Even a missing comma can cause havoc, as in this sentence: “Employing a straight platinum wire rabbit, sheep and human blood agar plates were inoculated. . . .” That sentence was in trouble right from the start because the first word is a dangling participle. Comprehension was not totally lost, however, until the author neglected to put a comma after “wire.”

Authors often are advised, quite rightly, to minimize use of passive voice. However, in the materials and methods section—as in the current paragraph—passive voice often can validly be used, for although what was done must be specified, who did it is often irrelevant. Thus, you may write, for example, “Mice were injected with . . .” rather than “I injected the mice with . . .”; “A technician injected the mice with . . .”; or “A student injected the mice with . . .” Alternatively, you may say, for example, “We injected . . .,” even if a single member of the team did that part of the work. (Although belief persists that journals prohibit use of first person, many journals permit use of “I” and “we.”)

Because the materials and methods section usually gives short, discrete bits of information, the writing sometimes becomes telescopic; details essential to the meaning may then be omitted. The most common error is to state the action without, when necessary, stating the agent of the action. In the sentence

“To determine its respiratory quotient, the organism was, . . .” the only stated agent of the action is “the organism,” and we doubt that the organism was capable of making such a determination. Here is a similar sentence: “Having completed the study, the bacteria were of no further interest.” Again, we doubt that the bacteria “completed the study”; if they did, their lack of “further interest” was certainly an act of ingratitude.

“Blood samples were taken from 48 informed and consenting patients . . . the subjects ranged in age from 6 months to 22 years” (*Pediatr. Res.* 6:26, 1972). There is no grammatical problem with that sentence, but the telescopic writing leaves the reader wondering just how the 6-month-old infants gave their informed consent.

And, of course, always watch for spelling errors, both in the manuscript and in the proofs. We are not astronomers, but we suspect that a word is misspelled in the following sentence: “We rely on theatrical calculations to give the lifetime of a star on the main sequence” (*Annu. Rev. Astron. Astrophys.* 1:100, 1963). Although they might have been done with a flourish, presumably the calculations were theoretical, not theatrical.

Be aware that a spell-checker can introduce such errors and therefore cannot substitute for careful proofreading. One recent example: a spell-checker’s conversion of “pacemakers in dogs” to “peacemakers in dogs.” We have known some dogs that could benefit from pacemakers, but we rightly suspected that this wording was not intended in writing about canine cardiology.