Introduction

The Introduction of a research paper sets the stage for your scientific argument. It places your work in a broad theoretical context and gives readers enough information to appreciate your objectives. A good Introduction "hooks" its readers, interesting them in the study and its potential significance. Thus you, as a writer, must have a firm grasp of the aims, principal findings, and relevance of your research. You may find that the Introduction is easiest to write *after* you have drafted the Materials and Methods, Results, and Discussion sections and have a clearer understanding of just what you are introducing.

■ Orient the reader by summarizing pertinent literature in your field.

An effective way to organize the Introduction is to proceed from the general to the specific, starting with a review of current knowledge about the topic and narrowing down to your specific research problem. Introduce key concepts, define specialized terms, and explain important hypotheses or controversies. As you do so, *document* your writing by citing key references in the field—more general ones first, followed by studies closest to your own research. (See Chapter 6 for instruction on how to document sources.) In this way you can sketch out a framework for the study, orient your readers, and prepare them for what is to follow.

Do not make the Introduction *too* broad or *too* detailed. This is not the place to show off your knowledge about the subject, list every available reference, or repeat material found in any elementary text. Most published papers have short Introductions (often only a few paragraphs) because the writer is addressing readers with backgrounds similar to his or her own. It wastes journal space and the reader's time to give an exhaustive literature review. Similarly, in a paper for a course, write for your classmates and your instructor—people with at least a beginning knowledge of the subject. Discuss only the most relevant concepts and references, and get quickly to the point of the paper.

■ Explain the rationale for the study and your major objectives.

After explaining the broad theoretical context, you are ready to clarify the special contribution your own study makes. How does your work fit in with that of other researchers? What special problem does your study address? What *new* information have you tried to acquire? Why? How? In other words, why (apart from course requirements) are you writing the paper in the first place? Most authors end the Introduction by stating the *purpose* of the study. For example:

The purpose of this study was to describe the dominant fungi associated with decomposing leaf litter in a small woodland stream.

In this paper, I present evidence that telomere length in *Schizosaccharomyces pombe* is regulated by checkpoint genes.

Remember to clarify the purpose of your paper by first explaining the rationale for the study. What needs to be improved in the following Introduction?

The purpose of this project was to study the algae at two different sites in Payne Creek, near Stillson, Florida. Chemical and physical parameters were also considered. The study involved algal distribution in several microhabitats of both stream and marsh environments. This project was part of a larger class study for Biology 341.

A major problem here is that the writer has not linked the study to a broader conceptual framework. She begins abruptly with a vague statement of her objectives, with no explanation of why they are important. The passage also contains irrelevant information: it is not necessary to state that the study was part of the requirements for a particular course.

By contrast, the writer of this Introduction gives the reader a clear idea of what the objectives are and why they are important:

It is well known that males of many species of dragonflies (order Odonata) guard their mates after copulation while the eggs are being laid. In some species the male hovers over the female and chases away other males; in others, the male remains physically attached to the female as she moves around the breeding site. Many authors have discussed the adaptive significance of mate-guarding, particularly with respect to ways in which it may increase the reproductive success of the guarder (for example, Alcock 1979, 1982; Sherman 1983; Waage 1984). A more complete understanding of the evolution of this behavior is dependent on detailed studies of many odonate species. In this paper, I describe mate-guarding in *Sympetrum rubicundulum* and discuss ways in which guarding may be adaptive to males.

Some authors end the Introduction by summarizing their major *results* in a sentence or two. This tactic gives readers a preview of the major findings and may better prepare them for the scientific argument that follows. Other writers, along with some journal editors, criticize this practice, arguing that results are already covered in their own section and in the Discussion and Abstract. Ask your instructor what he or she prefers.

Materials and Methods

■ Include enough information so that your study could be repeated.

Your methodology provides the context for evaluating the data. How you made your measurements, what controls you used, what variables you did and did not consider—all these things are important in molding your interpretation of the results. The credibility of your scientific argument depends, in part, on how clearly and precisely you have outlined and justified your procedures.

Furthermore, one of the strengths of the scientific method is that results should be reproducible using similar materials and methods. It is not unheard of for a scientist to repeat someone else's experiment and get different results. These conflicting data then point to factors that may have been overlooked, perhaps suggesting different interpretations of the data.

Finally, a complete and detailed Methods section can be enormously helpful to others working in the same field who may need to use similar procedures to address their own scientific problems.

What kinds of information should you include? See the guidelines below.

Materials

1. Give complete taxonomic information about the organisms you used: genus and specific epithet as well as subspecies, strains, and so on, if necessary. Specify how the organisms were obtained and include other information pertinent to the study, such as age, sex, size, physiological state, or rearing conditions.

> *Cladosporium fulvum* race 4 was obtained from Dr. George Watson, Department of Biology, Colgate University, Hamilton, NY. Stocks were maintained in sterile soil at 4 °C and were increased on V8 juice agar at 25 °C in the dark. . . .
>
> Adult American chameleons (*Anolis carolinensis*), purchased from a local supplier, were used for all experiments. They were kept in individual terraria (30 × 30 × 30 cm^3) for at least seven days prior to the start of any study. They were provided with a constant supply of water and were fed crickets, mealworms, and other insects every two days. All chameleons were exposed to 15 h of fluorescent light daily (0800–2300), and air temperatures were kept at 30 °C. . . .

2. If you used human subjects, give their age, sex, or other pertinent characteristics. Biologists submitting papers for publication may need to demonstrate that subjects have consented to be involved in the study.

3. Describe your apparatus, tools, sampling devices, growth chambers, animal cages, or other equipment. Avoid brand names, unless necessary. If some materials are hard to obtain, specify where you purchased them.

4. Specify the composition, source, and quantities of chemical substances, growth media, test solutions, and so on. Because they are more widely understood, use generic rather than brand names.

> Sodium citrate, sodium pyruvate, and hydroxylamine were obtained from Sigma Chemical Company, St. Louis, MO. All chemicals were of reagent grade. . . .
>
> For the first series of electron microscopy studies, tissue samples were fixed in 2.8% ultrapure glutaraldehyde, 0.57 mol L^{-1} glucose, and 0.10 mol L^{-1} sodium cacodylate. . . .

5. If detailed information about any of the materials is available in a standard journal, then avoid repetition by referring the reader to this source.

> I used an intermittent water delivery system similar to that described by Lewiston (1950). . . .
>
> Tryptone-yeast extract broth (Pfau 1960) was used to cultivate bacterial strains. . . .

Methods

1. Describe the procedures in detail. Do not forget crucial details such as temperature conditions, pH, photoperiod, duration of observation periods, sampling dates, and arbitrary criteria used to make particular assessments or measurements. If you used a method that has already been described in a standard journal, you need not repeat all this information in your own paper; just cite the reference.

> Mycelia were prepared using the fixation and embedding procedures described by Khandjian and Turner (1971). . . .

However, if the reference is hard to obtain (for example, *The Barnes County Science Newsletter*), or if you altered someone else's methods, then supply full information about your procedures.

2. For field studies, specify where and when the work was carried out. Describe features of the study site relevant to your research and include maps, drawings, or photographs where necessary. If published information already exists on the area, cite sources.

> This study was conducted during June and July 2005 at Bog Pond, 3 km northwest of Barrow, West Virginia. The general habitat of this pond has been described elsewhere (Needham 1967; Scott 1981). The pond is permanent and contains floating and emergent vegetation (mostly sedges, rushes, and algae). It has an area of approximately 1.5 ha. . . .

3. Commonly used statistical methods generally need no explanation or citation; just state for what purpose you used them. If you used less familiar or more involved procedures, cite references explaining them in detail and give enough information to make your data meaningful to the reader.

■ Organize your material logically.

Because the Materials and Methods section contains so many important details, it is easy to forget some, particularly because you are so familiar with the subject. It is also easy to let this section become a confusing, rambling conglomeration of details, with little unity or coherence. Organize this section carefully using an outline, a list, or a plan, along with the detailed notes you compiled while doing the research.

A typical approach is to begin with a description of important materials (study species, cell cultures, and so on) and to move on to the methods used to collect and analyze the data. Field studies often start with a description of the study site. Describe your procedures in a logical order, one that corresponds as closely as possible to the order in which you discuss your results. You may also group related methods together.

Remember that the Materials and Methods section is still part of your text and must be readable. Do not let your paragraphs become disorganized collections of choppy sentences, as in the example below:

FAULTY

Golden hamsters (*Mesocricetus auratus*) used for this research were adult males. Temperature conditions were kept at 22–24 °C. Animals were fed Purina chow. Hormonal studies were performed on 23 individuals. The photoperiod was 16 h. Animals were housed with littermates of the same sex, and feeding was once each day. All hamsters had been weaned at 3 wk.

REVISED

Hormonal studies were performed on 23 adult male golden hamsters (*Mesocricetus auratus*). All had been weaned at 3 wk and housed with littermates of the same sex. They were reared under conditions of 22–24 °C and a photoperiod of 16 h and were fed Purina chow once daily.

The revised passage is easier to read and understand. Short, choppy sentences have been combined, and related points have been pulled together. The same information is conveyed using fewer words and a more organized style.

If the Materials and Methods section is longer than several paragraphs and involves lengthy descriptions of several topics, you may wish to use *subheadings* (perhaps taken directly from your outline) that break the text into clearly labeled sections (for example, Study Area, Sampling Methods, and Data Analysis; or Test Water and Fish, Testing Conditions, Chemical Analyses, and Statistical Analyses; or Plant Material, Morphometry, Light Microscopy, and Electron Microscopy). Make your subheadings general or more specific, depending on the type and amount of information you need to relate. If you use many specialized or invented terms to report your results, they may be put in the Methods section under Definitions. Using subheadings makes

your text easier to write and to read, and it prods your memory for stray details on all aspects of the study.

■ Use specific, informative language.

Give your readers as much information as you can. Replace vague, imprecise words with more specific ones, and quantify your statements wherever possible.

VAGUE I observed some monkeys in a large outdoor enclosure and others in small, individual indoor cages.

SPECIFIC I observed 13 monkeys in an outdoor enclosure ($10 \times 8 \times 12$ m^3) and 12 others in individual indoor cages ($1 \times 2 \times 1$ m^3).

VAGUE Several pits were dug at each forest site, and soil samples were collected from three different depths in each pit.

SPECIFIC Four randomly located pits were dug at each forest site, and soil samples were collected from three depths at each pit: 0–5 cm, 6–11 cm, and 12–17 cm.

VAGUE Root nodule tissue was stained with a number of histochemical reagents.

SPECIFIC Root nodule tissue was stained with toluidine blue, Schiff's reagent, and aceto-orcein.

VAGUE Every nest was checked frequently for signs of predation.

SPECIFIC Every nest was checked twice daily (at 0800 and 1600) for signs of predation on eggs or nestlings.

■ Understand the difference between the active and the passive voice.

In the passive voice, the subject of the sentence *receives* the action:

Lizards (SUBJECT) *were collected* from three different sites.

However, in the active voice, the subject *performs* the action:

I (SUBJECT) *collected* lizards from three different sites.

Decisions about whether to use the passive or the active voice arise most often in the Materials and Methods section of research papers. Use of the passive voice is widespread in scientific writing, even though the active voice is generally more direct and concise. However, the passive voice focuses the reader's attention on the objects being studied or manipulated rather than on the researcher, and for this reason the passive voice often

writers find that a carefully constructed mix of active and passive sentences works best.

The passage below, from the Methods section of a paper by Burger (1974, p. 524), illustrates an effective mix of active and passive voice:

> I used several marking techniques on nests, adults, and juveniles. In 1969, I marked nests with red, blue, and white plastic markers tied to cattails. . . . Markers placed on nests were subsequently covered with fresh nest material. Adults were captured with a nest trap . . . and marked with coloured plastic wing tags (Saflag). I marked pairs who were close to the blind by pulling a string attached to a cup of red dye suspended over the nest.

Notice that the author of this passage uses several first-person references (*I* used . . . ; *I* marked . . .). Today many biologists are writing "I" instead of impersonal and cumbersome language such as "this investigator" or "the author." This use of the first person makes their prose more direct and concise. It may also reflect a growing realization by biologists that there *is* an "I" in science—that scientific research is inevitably influenced by the personal background, interests, motives, and biases of each researcher.

See Chapter 7 (p. 165) for more information on passive and active voice.

■ Omit unnecessary information.

Include only those procedures directly pertaining to the results you plan to present. Do not get carried away in your desire to include all possible details. The reader is not interested in superfluous details or asides, and in published articles such material just wastes space and raises printing costs. The following example includes many unnecessary details:

> Fathead minnows were collected from Lost Lake, near Holmes, NC, and transported back to the third-floor laboratory in large white pails. On the following Tuesday morning, skin for histological examination was taken from the dorsal part of the fish just behind the anterior dorsal fin.

Do we really need to know that the fish rode to the lab from the lake in large white pails? Or that they were taken to that particular laboratory? Or that histological studies were done on a Tuesday?

Notice how much clearer the following example becomes when superfluous details are removed:

FAULTY

> After considering a variety of techniques for determining the sugar content of nectar, I decided to use the method developed by Johnson (2004), because it seemed straightforward and easy to follow, especially for someone with a poor mathematical background.

REVISED

> I used Johnson's (2004) method to measure the sugar content of nectar.