

too many hypotheses; bad analytical or statistical methods; poor experimental design; weak questions; good big picture but inappropriate tests for that question; too ambitious a project for the time and money requested; inadequate skills or credentials for the task proposed. Finally, there are a number of procedural pitfalls that are to be avoided at all costs. Most of these are obvious but can be critical. For example, avoid alienating the reviewers by permitting typographical errors, erroneous references, or incorrect or inconsistent numbers to creep into the text. Follow all page length guidelines! Present a pleasant-looking document that is legible and logical and, whenever possible, reader friendly. Again, evaluating other proposals and looking at your own project with these specific issues in mind is of great benefit throughout the writing process.

An excerpt from:

Friedland, A.J. and C.L. Folt. 2000. *Writing Successful Science Proposals*. Yale University Press, New Haven & London. pgs 5-17.

Developing Your Conceptual Framework and Significance Statement

Scientific proposals are always judged by their perceived significance. This is true whether you are writing for the NSF, the American Heart Association, a local conservation society, or a dissertation committee. Everyone who funds or supervises research inevitably asks what makes the proposed research "significant." If you cannot answer this question, stop writing and keep thinking.

All of the scientists we asked agreed that time spent early developing a proposal's significance, objectives, and hypotheses is time well spent. Remember that persuasive questions are essential for successful proposals.

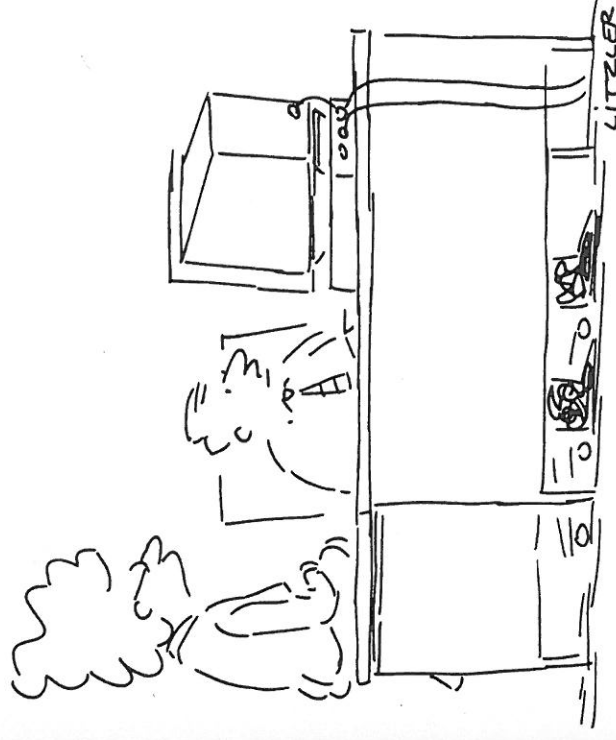
Four cornerstones underlying good research are:

- Important questions
- The best and most appropriate methods
- Appropriate analysis and application of results
- Synthesis and timely dissemination of results

In this chapter we provide suggestions for conceptualizing and developing the first of these cornerstones, and offer simple guidelines for writing a compelling significance section and placing it strategically in your research proposal.

Developing Your Significance Statement

The questions to be addressed by the study generally are featured with their justification in a significance section. Many scientists feel that this is the most important piece of a research proposal. A well-written significance section highlights the fundamental value of the proposed research, so we suggest that you start the research unit with a significance section (see also Chapter 3). This section should be linked to the specific



"I'M AT THAT AWKWARD STAGE IN THE PROPOSAL WHERE I HAVE TO ASK FOR SOMETHING."

objectives and hypotheses (discussed in Chapter 7) of your study, which should follow closely in the proposal. The reviewer must find that the logic in this section is sound, that the ideas are exciting, and that the scope is reasonable within the time and budget you propose. Obviously this is not a trivial job.

To refine your thinking on the significance of your research, step outside your own discipline and immediate needs and take a broad and long-term view of your research. This perspective is essential for building a valuable and wide-reaching set of hypotheses. The goal is to end up with a pithy and accurate statement of the significance before you write the section. While writing or evaluating the significance section of a proposal we suggest that you:

- Look at the project from both a broad and narrow disciplinary view.
- Ask what scientists *inside* versus *outside* the field would perceive as the greatest contribution of this research.
- Consider both the empirical and theoretical contributions that may result from the study.
- Identify and contrast basic and applied uses of the data.

- Ask how you most expect and hope your research will be used by others.
- Compare contributions of the project that are likely to be important one year versus ten years after the completion of the project. Remember that the significance of a project changes with time and new technologies.
- Be your own best critic and ask how an impartial reader would dispute the claims that you have made.

Exercises for Developing Your Significance Statement

The following exercises help you to conceptualize and articulate your research proposals *before* you begin to write. View these drills as the building blocks for writing the entire proposal, and follow the four precepts for effective communication (organize, highlight, funnel, and focus) while doing them.

EXERCISE 1: Prepare a ten- to fifteen-minute oral presentation of the conceptual framework for your proposal. Restrict yourself to the use of three overhead

transparencies. The challenge is to present the conceptual framework without reference to any specific system. For example, suppose you plan to investigate synergistic effects of exposure to toxic metals on reproduction and growth of oysters in estuaries off the Maine coast. For this exercise, distill the key conceptual points of your proposal: those ideas that are of importance *beyond* oysters, the specific metals you'll study, and estuaries in Maine. For example, you could focus on understanding synerisms among contaminants that occur in combination. The point of departure for your talk could be the need to tease apart mechanisms of interactions among contaminants in order to devise remediation strategies.

This activity forces you to articulate your general research question in broad terms, and to relate your study to the theoretical and empirical research that precedes it. If you must use a system to illustrate aspects of the discussion, do *not* use the system you intend to study. If you are doing this as a written exercise, confine your writing to a single page.

EXERCISE 2: Distill your previous presentation to a five- to ten-minute oral presentation of the significance and broad objectives of your research. This time you can refer to the specific system, cells, or organisms that you actually plan to study. When you can

do this effectively you are probably ready to write a project summary and a brief yet pointed introductory significance statement for your proposal (see Chapter 6).

EXERCISE 3: Prepare a ten- to fifteen-minute presentation of the conceptual framework for your research project, focusing on the underlying quantitative, theoretical, and functional relations. Proposals often include or require a model or series of models to identify the key relations between processes (see Chapter 8). As in exercises 1 and 2, emphasize the relation between your study and the theoretical and empirical research preceding it. This exercise is usually accompanied by a graphic presentation of the conceptual or quantitative relations. Successful completion of this exercise can produce a piece to be used in the introduction and justification of your study.

EXERCISE 4: Identify a system (e.g., biochemical process, species, habitat) that is as analogous to the one you plan to study as possible. Give another five-minute oral presentation (or prepare a one-page written summary) on the significance and broad objectives of your research, this time structured entirely around the comparable system. This exercise forces you to consider the relations between significance and specific objectives more precisely, because sometimes objec-

tives may not be as generally applicable as believed.

This may make you reevaluate your objectives with respect to your chosen study system.

Crafting the Significance Statement

An effective, engaging significance section motivates the reader to give your proposal a thorough appraisal, and it establishes the framework for the rest of the study. The overall goals and significance should also target information necessary in the background section (Chapter 10) and lead the reviewer directly to the objectives and hypotheses or specific research questions. If the significance section is not consistent with the other sections, your proposal will not be persuasive.

A formulaic approach is rarely wise, yet we agree with the widely held philosophy that an effective significance section (generally one to two pages) begins with the “big picture” motivating your work, elaborates on the scientific context for your study, describes briefly your own research plans, and restates the overall goals and expected results. Here are several tips for

producing your significance section, compiled from our reviews of a number of excellent proposals.

- *Feature the significance section at the start of the proposal.* This allows you to set the tone for the entire proposal. Some people place the significance section at the end of the proposal, but we find that this is much less effective. By that point most reviewers will have already formed a firm opinion of the study.
- *Keep the section short.* Don't dilute your message with detail, but be sure to elaborate beyond the project summary (see Chapter 6).
- *Funnel the reader.* Take the reader from your broadest goals to your specific aims. The more effective your funnel, the clearer the section will be. If you can write a statement in which your research appears to be the most logical and innovative approach to answering the question raised in the first or second sentence, you will have accomplished a great deal.
- *Explain the value of your work.* It is essential that you explain the value of your research questions in a manner that is accessible and convincing to scientists both in and out of your immediate dis-

cipline. Perhaps you have identified a glaring gap in knowledge. If so, explain what information is missing and describe how finding that information may lead to other important research. Maybe you plan to work on a process that has been identified in one system but not tested in other systems. You must convince the reader that testing the process in another system is important in some fundamental way. After reviewing this section the reader should understand how the successful completion of your work will advance the state of science in your field.

- *Link with other fields.* Successful research usually has significance beyond its immediate domain. Briefly explain the implications of your work for other fields, and how it can be applied in those fields. This makes your work more appealing, and it emphasizes that your study has breadth.

- *Don't go overboard.* One important note of caution—be sure not to overreach. Reviewers become annoyed if the claims for significance are out of proportion to the research.

You can accomplish your task in a variety of ways. When composing the significance section, peo-

ple often go back and forth between significance, objectives, and methods. We usually first write a rough draft of the significance section, develop the objectives and hypotheses, consider the methods, and then reconsider and rewrite the significance section. When writing this section, remind yourself of some often-encountered pitfalls: language that is too vague, use of overblown or naive statements of significance, repetition of other sections without additional detail, and confusing or jargon-heavy language that fails to engage the reader. As we stated earlier, it is usually most effective to delay writing until you have completed the thinking for this section and read a number of proposals in your discipline.

More Exercises for Writing the Significance Section

To help hone your skills, we suggest that you critique the significance paragraphs of other proposals. We do this in the classroom, using a supply of proposals given to us by their authors. With our students we evaluate the effectiveness of significance sections based on content, perceived importance of the questions, placement in the grant, basic writing skills, and

style. This activity is valuable at any time in the development of a proposal.

Experiment with names for this section. Different titles are commonly used. Some are more forceful than others, depending on the type and objectives of the proposal. Here are some examples from successful proposals. Which do you prefer?

- Overall Objectives
- Overview and Significance
- Significance and Project Objectives
- Statement of the Problem

Critique other significance sections. Consider the following excerpts from three significance sections and one entire significance section. Are they cogent? Are you engaged? Do they successfully cover some of the points listed above? Are the primary pitfalls avoided?

Field Measurements of Phytochelatins in Crops and Ecosystems Contaminated by Metals*

Understanding how metal pollutants affect crops and forests is obviously of great importance to U.S. agriculture. Much research is aimed at elucidating the mechanisms of plant-metal interactions, including the induction of phytochelatins.

Source: F. M. M. Morel, excerpted from the Rationale and Significance section

*Phytochelatins are peptides, naturally produced by plants, that bind metals

Quantification of Base Cation Sources and Cycling in a Forest Ecosystem Using Strontium Isotope Tracers and Mass Balance Methods

The proposed research should yield new estimates of internal ecosystem cation fluxes such as canopy leaching and release during organic matter decomposition. These elemental transfers are generally determined as the residuals in mass balance studies. Strontium isotopic tracer methods will provide independent estimates of these important cation fluxes. . . .

The results of our proposed research will be applicable to the greater Adirondack Mountain area as anorthositic and granitic rocks are the major parent materials in this region. . . .

Source: E. Miller, A. Friedland and J. Blum, excerpted from the Significance section

Understanding Hydraulic Conductivity in Aquifers from Above-ground Measurements

Understanding hydraulic conductivity of a variety of aquifers has global importance and cannot be undervalued given the enormity of environmental problems related to contamination of aquifers. Our proposed technique, if successful, has the potential to revolutionize the way that groundwater studies are conducted. It may also greatly affect the rates of species extinction, global warming, and frequency of El Niño events.

Source: Excerpted from the Significance section of a fictional proposal

Do you think that the relative weights given to justification of the big picture and its link to the aims of the study are effective in the following example?

Metal Accumulation in Aquatic Organisms

Metals enter aquatic food webs in several ways, ranging from atmospheric deposition to surface or groundwater flow of metal enriched water. Once in lakes, metals become incorporated in the food web via direct uptake from the water or the ingestion of metal-bearing foods. Large changes in species composition, species diversity, biomass, and growth of aquatic organisms have been measured in metal-impacted lakes. In some lakes, fisheries have declined seriously and the accumulation of metals in fish tissue has been recognized widely as a human health hazard. Mercury is of special concern, because elevated levels of mercury have been found in fish from a large number of lakes in remote areas not associated with local sources of contamination.

Aquatic organisms accumulate metals in their tissues from their diet. Bioaccumulation is the general process by which metals are taken up directly from the water and the food. Biomagnification describes a systematic increase in the concentration of metals (or other chemicals like DDT and PCBs) in tissue as the chemical moves up a trophic food web (i.e., from algae to zooplankton to fish). Not all metals bioaccumulate, but all do bioaccumulate. Metals such as lead and cadmium bioaccumulate, but may not biomagnify. In contrast, mercury bioaccumulates and biomagnifies, which can result in very high concentrations of mercury in fish from lakes with low mercury levels in the water.

Complex biological mechanisms and relationships make it impossible to simply predict the risk of exposure to metals from the metal concentration in the water. Prior studies on bioaccumulation and biomagnification of metals

have shown that the differences in the concentration of metal in fish tissue (body burden) result from species- and age-specific behavioral and physiological traits. For example, species with feeding behaviors that increase exposure (e.g., benthic feeders are highly exposed to metals in sediments) carry higher body burdens. Physiological mechanisms that strip metals reduce body burdens in some species but not others. For metals that biomagnify, the trophic position of the fish has a profound influence on body burden. Predatory fish (high on the food chain) have higher body burdens of mercury than planktivorous fish (lower on the food chain) of equal body size. Hence, the body burden of metals in fish can be understood only by considering the food web relations in lakes.

To date, there are very few lakes for which food web relations, metal concentrations, and body burden values are known. This information is critical for assessing the current level of risk to humans and aquatic organisms and for developing predictive models for the functional relations between such important measures as body burden, food web composition, and water quality. The aims of the proposed study are to measure variation in the bioaccumulation and biomagnification of toxic metals in lakes, with dual goals of understanding effects of hazardous substances on ecological systems, and the role of food web structure in determining bioavailability of metals to humans. Metals with different potential for bioaccumulation and biomagnification will be contrasted . . .

Source: C. L. Folt, C. Y. Chen, and R. L. Stemberger, modified from the Significance section

Write your own significance section. After you

have written a significance section, ask friends and colleagues to read it. Keep in mind the essential points to cover and the pitfalls to avoid. If you have a solid, persuasive significance section, you are well on the way to completing a successful proposal.

C H A P T E R 5

A Title May Be More Important Than You Think

Titles are often written at the last minute and typically receive less thought than the rest of the proposal. But the title introduces your reader to the framework and perspective of the document. An effective title will capture that reader's attention and prepare the reader for the focus you wish to establish. The role of the title can be significant during the evaluation process, in which a review committee may collectively assess up to two hundred proposals. In some cases, members of a review committee may start by reading the applications with the most intriguing titles. It is advantageous to get a reviewer's attention when she is freshest and most receptive to new ideas.