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# Writing Successful Science Proposals

C H A P T E R 7

## Objectives and Hypotheses: An Exhaustive List Is Exhausting

A beautifully crafted document, or a convincing and exciting significance statement, means little if the research objectives and tests are ill conceived, poorly stated, or absent. Our class concentrates heavily on constructing, deconstructing, and reconstructing each others' objectives and hypotheses. If working alone, you might want to find a few colleagues who are willing to exchange ideas. Reviewing your hypotheses and objectives with others may be one of the most beneficial activities you can pursue.

Development of hypotheses generally precedes proposal writing. Most readers of this book probably have already identified a series of objectives and associated hypotheses. Solicit feedback prior to writing by presenting these hypotheses to colleagues and mentors

to determine whether they are rigorous, testable, and engaging. The goal now is to articulate those ideas in writing and to place them into a proposal. A key aspect of this process is making sure that the hypotheses are consistent with the significance statement and linked properly to the objectives.

## Objectives versus Hypotheses

Objectives usually refer to broad, scientifically far-reaching aspects of a study, and sometimes they verge on significance statements. If both significance statements and objectives are included, the objectives generally are more focused. Objectives can also pertain primarily to contributions or novel uses of the data within the scientific community. We label these objective statements Type 1 and Type 2. The following examples are modified from proposals that we have written or that have been shared with us by the authors.

Our objectives are:

- to further our understanding of the implications of global climate change in freshwater lake plankton communities. (Type 1)
- to lead to more informed policy decisions about the effect of electromagnetic radiation on humans residing near high-voltage power lines. (Type 2)

- to understand how cell division and differentiation are regulated by a myriad of extracellular and intracellular signals. (Type 1)
- to evaluate mechanisms leading to species coexistence in marine intertidal communities and compare magnitudes and scales of effects. (Type 1)
- to provide the first complete data base for the assessment of toxic metals on reproduction. (Type 2)
- to develop an analytical framework for classifying brain potential analysis of motor function and decisions. (Type 1)

Hypotheses usually refer to an even more specific set of testable conjectures than do the objectives. A well-formulated hypothesis leads directly to the experiments and sampling programs that form the basis for the research. Keep the number of hypotheses reasonable: it is important to strike the proper balance between too many and too few. If you present too many, your proposal will confuse the reader and reduce its effectiveness. One of us wrote a proposal with twenty-seven hypotheses. Rather than being dazzled with the breadth and depth of thinking and synthesis involved in the study, the reviewers were baffled and bored. They also perceived a lack of focus—no surprise! After the proposal was rejected, the program director suggested reducing the number of hypotheses to five or fewer to focus the effort. We agree with that general

recommendation, though there is no magic number for how many hypotheses to include.

We have adapted some hypotheses from our own and others' proposals. Is it apparent how these hypotheses differ from general significance statements or objectives?

- We hypothesize that lead is complexed by a chelating agent associated with adventitious roots, transported across the membrane, and stored in the inner cortex.
- Channel roughness is greater, and velocity, stream power, and shear stress are lower, in restored reaches versus unrestored reaches.
- Differences in temperature and humidity among sites persist across years, despite natural yearly variation in climate and other environmental variation.
- Zinc can effectively compete with other metals for enzyme-active sites, transporter proteins, and other biologically important ligands.
- Mineral weathering in the lower soil horizons provides most of the cations lost from the ecosystem to stream water.

## Linking Objectives and Hypotheses to the Significance

Although objectives, hypotheses, and overall significance refer to different key features of a research proposal, they are tightly linked and must work well to-

gether. Each relies on the other for its validity and purpose. The significance statement is the most general and far-reaching description of the research; objectives are usually more focused than is the significance, and hypotheses are more specific than are the objectives. Objectives and hypotheses are more likely to identify particular processes, organisms, or locations than are significance statements.

To illustrate the relation between significance, objective, and hypothesis, we return to an example from Chapter 4 (from F. M. M. Morel). In this example, the overall *significance* statement introduces the topic of metal pollution and its major effects on agriculture as the overall focus of the study:

Understanding how metal pollutants affect crops and forests is obviously of great importance to U.S. agriculture.

One of the *objectives* in that same proposal identifies the metal pollution of interest as coming from smelters and being airborne:

[We wish to determine whether] in areas of high metal pollution, such as those near smelters, are plants exposed to metal stress through direct airborne pollution or [indirectly] through accumulation in soils?

Later on, the author presents this *hypothesis*, which names the metals as Ni and Cu, the mechanism as at-

atmospheric deposition, and the focal plant species as paper birch:

To investigate the hypothesis that current atmospheric deposition of nickel and copper aerosols is the dominant source of metal stress in vegetation surrounding Sudbury, Ontario, seedling of *Betula papyrifera* will be placed at each sampling location.

Note how the author becomes increasingly specific in the move from significance to objectives to hypotheses, and how each is closely linked to the others.

Here is another illustration of the progression. The *significance* statement is broad in scope and relates to a problem of international concern, namely global climate change. In creating this example we deliberately avoided the popular terminology, but that is a matter of personal preference:

We wish to understand the biological implications of projected increases in global temperature on fish populations.

The *objective* is much more precise and is directed to a particular type of system (salmonids on the rearing grounds), yet it remains somewhat inclusive (not regionally focused, nor species specific):

We will quantify responses of salmon to predicted increases in summer temperatures in their rearing grounds.

Finally, the two *hypotheses* that derive from this objec-

tive lead directly to an easily identifiable set of experiments or measurements. They are species-specific and address certain demographic traits and rates:

A water temperature increase of 1°C in May will advance the hatching date of Atlantic salmon by 2 weeks.

Advancing the hatching date of Atlantic salmon by 2 weeks will reduce survival rates.

In this example we also have become increasingly specific, moving from significance to objectives to hypotheses.

## Placement in the Proposal

Successful proposals often feature significance, objectives, and hypotheses sections near the start of the proposal, but there is no specified location for them. Authors usually introduce objectives and even hypotheses in the project summary or aims, and the objectives almost always appear in the significance section of proposals. You need to strike a balance between early presentation and appearing repetitious when you discuss the same material in greater detail in later sections. Many authors insert the hypotheses in a number of locations in a proposal, presenting greater detail with each mention.

In the following example, the general hypothesis is first stated in the title and then repeated with greater detail, and in a different fashion, in various sections of the proposal:

- *Title.* "The Role of Temporal Control Genes in Specifying the Timing of Events in the Nematode *C. elegans*"
- *Project summary.* "The broad goal of this work is to understand the genetic and molecular mechanisms of the temporal control of cell division and differentiation using the nematode *C. elegans* as a model.
- *Introduction and background.* "Animal development is a complex schedule of processes that are controlled by genetic and other factors."
- *Significance section.* "The *C. elegans* genes offer an opportunity to study the genetic and molecular mechanisms controlling cell division and differentiation, processes central to all multicellular development."
- *Research design and methods.* The hypotheses are presented in a preface to each set of experiments which are designed to test them.

Source: V. Ambros

Regardless of where you cite your objectives and hypotheses, and depending on the requirements of your funding agency or dissertation committee, using headings and subheadings highlights the importance of objectives and hypotheses within the proposal. It also makes it easier for the reviewers to find them. Be sure to follow the conventions of your field. For example, the practice in some fields is to use the traditional null hypothesis; that is, no matter what you think the outcome of your study might be, you state that there will be no effect (e.g., "The test drug will have no effect on the population."). Other fields are more accepting of positive hypotheses ("The test drug will reduce symptoms in more than 75 percent of the test population."). The terminology used may also vary across disciplines (e.g., hypotheses are sometimes referred to as questions).

## Exercises for Writing Objectives and Hypotheses

Our class uses the following exercise to formulate a very tight set of hypotheses prior to writing the accompanying text. This formulation step may take several weeks as you review the critical feedback on your objectives and hypotheses and then revise and re-