```
covered that a detonation sweeps through an explo-
sive as a supersonic shock wave, driven by the en-
ergy-releasing chemical reactions that the wave
induces. Controlling this shock wave may in turn
contain the direction of the explosion, directing
the force of the explosion in a more concentrated
fashion against its objective. Based on these
findings, our recommendation is to concentrate fu-
ture efforts on discovering such controls of the
shock wave.14
```

SOME FINAL WORDS ABOUT ABSTRACTS

Whole books have been devoted to writing abstracts in science. Abstract are one of the most important parts of professional science writing, yet very few students during their college careers get much practice in writing them. It takes practice to get the knack. You will also find that writing abstracts is an important cognitive exercise that provides you with a concrete overview of your own work. Writing the abstract forces you to pare away the inessential and define the essential.

8

How to Write the Introductory Section

The *introduction* to a research paper should accomplish three things:

1. It should provide a larger context for the problem.
2. It should state and explain the problem in specific terms, restricting the scope of the problem to the one actually described in the paper. In some instances, the introduction should also suggest an answer to the research question in the form of an hypothesis.
3. It should give some sense of the paper's organization.

The major challenge in writing the introduction is knowing what to include or how broadly to begin in creating a context for the topic.

TAKING TOO BROAD AN APPROACH

I wish I had a dollar for every student paper I've read that began with some wonderfully sweeping vista.

X: "Ever since the dawn of mankind, when the earliest cave dwellers first discovered fire. . . "

X: "From the very moment the universe was born. . . "

The impulse behind these opening statements is a good one: The writers sense that it is important to establish a broad context and relevance for their work. It might even be possible to construct a scientific paper in which these sentences might pass muster. However, these sorts of introductions almost certainly begin with too wide a field of vision.

The introduction should orient the reader not with respect to the whole universe or all of human history or to fundamentals, but to unmistakably important and relevant contexts for the problem at hand.

TAKING TOO NARROW AN APPROACH

On the other hand, it is much more common—and in some ways more unsettling—to read scientific reports that plunge right in with extremely specific, technical statements. These introductions give the reader no orientation and set no context for understanding the importance of the research.

X: Guanine nucleotide binding proteins participate in eukaryotic signal transduction.

X: The probability for dissociation of CH_4 on Ni(111) to produce an adsorbed CH_3 species and an adsorbed H atom has been measured as the function of the translational energy of the incident CH_4 molecule.

X: The source of turbulent mixing in the stably stratified, nondouble-diffusive parts of the ocean interior is thought to be instability of internal wave fluctuations.[15]

These may be suitable for short technical notes or correspondences, and you may even find that these sorts of introductions predominate in very specialized journals. But you should not assume that since they are so common, they represent best practices.

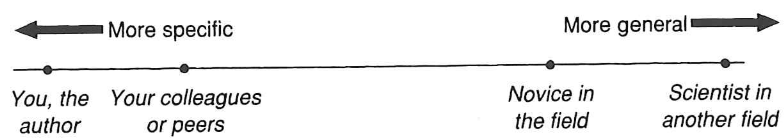
Such introductory statements may define the problem and "locate" the reader, but only in the very narrowest sense. They presume a reader who is already very close to the subject. In fact, they presume an audience that knows almost exactly what the author knows. There is the danger: You may think that the purpose of the work is obvious to other experts like yourself, but can you be sure? And can you be sure that only specialists—in this narrow sense—are reading your work? Common sense dictates that you try to broaden the context and make your introduction more explicit, even if only with a brief sentence or two.

FINDING THE MIDDLE GROUND

Many scientists have a natural fear of stating the obvious. When writing the introduction, many authors in the sciences think something like this:

> If I state the obvious, then my readers may think that I am trying to state something new when in fact I'm presenting stuff that's old hat to them. Therefore, they will think I am less knowledgeable about my subject than I should be, and I will appear foolish or inexpert.

There are two problems with this thinking. First, it is very difficult to decide what is "obvious": what one person understands clearly may be rather obscure to another. And certainly, in some senses, since you are writing the paper and you know the subject, it is *all* obvious to you. So there's a sliding scale of obviousness, with you at one end and some unknown reader at the other end for whom all of this is news.



It is much worse to err on the side of obscurity than on the side of giving too much information. Remember, the primary goal of your writing is to communicate. If you lose 25 percent of your audience because you did not locate the subject generally enough or explain the subject clearly, then you have failed in your primary mission.

Finding the Proper "Pitch"

A better way to approach the introduction is to think about finding the proper "pitch." In order to do so, you must know your audience and orient them.

Use the Introduction to Explain

State as clearly as possible the problem that your paper addresses and what special factors you considered in defining it.

Use the Introduction to Contextualize

Place the problem in context by citing the work of others who have also attacked the problem. Explain what is *new, important,* and *rele-*

vant, in your approach even if you think this is going to be obvious to many of your readers. Explain how it will extend or contrast to the work of others. This will help your reader locate your work in relation to others. If you can't describe the intrinsic interest of your work, at least for somebody somewhere, then you probably don't have much to report and should go back to the drawing board.

Use the Introduction to Define

Define new terms and concepts and explain special uses of familiar terms.

Here is an introduction to a research paper by Fujita, Lazarovici, and Guroff, published in *Environmental Health Perspective,* that does all the above while retaining its specificity:

CONTEXT: Between 1948, when the first experiment on nerve growth factor (NGF) was published, and 1976, when the first report on PC12 cells appeared, there was relatively little progress toward understanding how nerve growth factor acts on its target cells.

EXPLANATION: The reason for this difficulty is that the classical targets of nerve growth factor, sympathetic and sensory neurons, are difficult to harvest, difficult to culture, and above all, absolutely dependent on nerve growth factor for survival. Thus, any experiments directed toward the biochemical or molecular consequences of nerve growth factor action on these cells suffered from the criticism that the controls, those not given nerve growth factor, were dying. In short, it was difficult if not impossible to say whether a given biochemical response was a specific action of nerve growth factor or simply a result of the fact that the cells were not dying. Clearly, a tool was needed with which to study the actions of the factor apart from living cells. Such a tool was provided by the development of PC12 cells.

DEFINITION: These cells are currently the premiere tool for the study of nerve growth factor, but, more than that, they have become a very important model for the study of neuronal differentiation. Indeed, the findings with PC12 cells, in some cases, have implications for differentiation of cells in general.[16]

It is very likely that most of the readers of this article are more or less familiar with this history of the problems involved in studying nerve growth factor in living cells. Yet going over the history places all the readers on a common ground and helps refresh the memories of those readers who may not be sure of the precise problems involved. And of course, it helps to inform novices in the field.

The next example, by Kapuleas, from the *Annals of Mathematics,* illustrates how you can be extremely technical and specific, but still provide the important context—in this case the historical context—of a problem in topology, a branch of mathematics. Here, the language is very technical, but despite the specificity of the subject, the author has taken the time to give an historical background.

A soap film in equilibrium between two regions of different gas pressure—in zero gravity—is characterized mathematically by the fact that the surface it defines has nonzero constant mean curvature. It is an old problem in classical differential geometry to decide which finite topological types of surfaces can be realized as complete, properly immersed, or embedded surfaces of nonzero constant mean curvature in $\underline{E}^3$. Very little is

> known in this regard. For a long time, the only known examples of such surfaces were, besides the round sphere and the cylinder, a family of rotationally invariant surfaces discovered in 1841 by Delaunay [D]. In 1853 J. H. Jellet [J] studies the star-shape surfaces of constant mean curvature. In 1900 Liebmann proved that a convex sphere of constant mean curvature in $\underline{E}^3$ is round. S.-S. Chern extended Liebmann's result to a certain class of convex W-surfaces.
>
> Hopf established that constant mean curvature characterizes the round spheres among all topological spheres and asked whether it does so among all closed surfaces. Alexandrov answered in the affirmative for embedded surfaces. . . . Eventually H.C. Wente in 1984 disproved the so-called Hopf conjecture by constructing infinitely many immersed tori in $\underline{E}^3$ of constant mean curvature.[17]

Even in mathematics, where problems sometimes seem to simply materialize from some pure and abstract realm, there are historical contexts which help situate the reader in relationship to your work.

A DIGRESSION ON THE QUESTION OF WHERE PROBLEMS COME FROM

As a student you seldom get a chance to set your own problems and pursue them experimentally. In the context of a course, most problems are assigned to you. But it is important to imagine the conditions under which you would be defining and choosing your problems as a professional scientist. Very few scientific projects are *sui generis*—self-created out of thin air on the basis of a striking observation by a solitary scientist.

Imagine that you are scientist about to embark on a new scientific project. You were probably drawn to it by what others have written—or not written—about the subject. Perhaps you have chosen to focus on a particular scientific problem because you were inspired by a direct observation of nature. Perhaps you observed some anomaly: something behaved strangely, in a way different from what theory predicts. Or perhaps you have always been fascinated by some aspect of nature: the blueness of the sky; the power of lightning; why children look like their parents; the way light works. Perhaps you had a humanitarian or utilitarian goal: you wanted to cure diabetes, make energy available to more people more cheaply, enable space travel, devise efficient ways to grow food. As you have become more expert you have defined more specific ways to approach these goals.

Part of becoming expert means learning what others have learned about research problems. As you get closer to defining your particular experiment or project, you read more narrowly, encountering more technical papers about a subject. You will be building on the work of others, directly and indirectly, and you want to make sure your work will contribute to and not repeat the work of others. In other words, you want to do something *new*.

New scientific problems, new research programs, tend to arise from the pool of information reported in journals and conferences by the network or community of scientists in the field. Scientists choose research problems because in reading the work of others or hearing a conference paper, they have learned something or something has struck their imaginations. While there are often other, institutional pressures on scientists to find a research problem, questions tend to arise from a larger pool of information.

DEFINE THE PROBLEM USING "PREWRITING" EXERCISES

A good way to define the problem is first to ask yourself what sort of general problem it is you're working on, and then ask more specific questions. If you can't write your problem in terms of a question, or if you can't explain it in simple or brief terms, chances are you aren't ready to write the report or even to undertake the research. You haven't defined the problem carefully enough, or the project isn't clear enough in your own imagination.

Writing can play a natural role in this part of the scientific method as well as in writing the paper. Writing specialists call this combination of mental exercise and writing "prewriting": preparation for writing the first draft of a paper or even embarking on a new project. In this exercise, you would write in order to define the problem by answering questions you pose to yourself.

What Am I Trying to Discover or Prove?

To show the usefulness of prewriting, consider the following excerpt from the introductory section of an article on the evolution of life on earth. It sounds as if it were taken directly from a prewriting exercise.

```
We will focus on certain lipid-like molecules
called aphipiles. Amphipiles play a crucial role
in understanding the origins of life because they
have the ability to assemble themselves into mem-
brane-like structures which form self-contained
microenvironments. The following questions about
amphipiles will help us understand the prebiotic
conditions under which life may have formed:

  1. What physical and chemical properties per-
     mit the self-assembly of certain molecules
     into membranous boundary structures?
  2. What components of the prebiotic environ-
     ment were probably used for assembling the
     earliest membranes?
  3. How could macromolecular systems involved
     in early life processes become encapsulated
     in amphipiles?[18]
```

Which Kind of Problem Am I Working On?

There are four general kinds of problems in science based on what a researcher wants to accomplish:

1. *Define or measure a specific fact or gather facts about a specific phenomenon.* That is, explain: how a phenomenon behaves (under given circumstances); what it is composed of; how it works; and/or how it happened.
2. *Match facts and theory.* Discuss why no part of current theory explains these facts; explain why these observed facts, behaviors, or phenomena contradict what current theory predicts; and/or develop another theory that will explain certain facts better.
3. *Evaluate and compare two theories, models, or hypotheses.* Discuss how current theory leads to these two contradictory conclusions, or explain that the behavior of this phenomenon under certain circumstances has not yet been tested to see if it agrees with current theory.
4. *Prove* that a certain method yields better data than other methods.

Now pose what it is you are trying to discover or prove as specifically, simply, and briefly as possible in terms of *why, when, how, where, what,* or, if you're a social scientist, *who.*

```
• Does ras p21 mediate insulin action?
• Can white dwarves have planets?
• Where do yellow-bellied sapsuckers migrate in
  April?
• When do retinal ganglia form in the human fe-
  tus?
• Does lowering heart rates affect coronary
  artherosclerosis?
• What is the chemical composition on Io,
  Jupiter's moon?
• What causes the uneven thickness and disrup-
  tion in the late Quaternary sediment cover on
  the continental slope off New Jersey?
• Why does La2CuO4 possess antiferromagnetism?
• Who is most likely to be found attractive to
  members of the opposite sex, all other fac-
  tors being equal: those with large pupils or
  those with small pupils?
```

RELATE THE PROBLEM TO THEORY

Undoubtedly, the answer to the question you've posed will either confirm or deny current theory. It makes sense, then, that you must

- explain the theory or model;
- describe what facts are already known that support or don't fit the theory;
- elucidate where or why the match or mismatch occurs; and
- state the problem in specific terms.

The following introductory paragraphs are taken from an article that tries to explain the origins of light elements in stars. It accomplishes the four tasks noted above in order.

EXPLAIN THEORY

Most of the elements that make up the solar system were forged during the course of stellar evolution. The process began billions of years ago when clouds of primeval matter condensed to form young stars. Within these stellar furnaces hydrogen and other light elements were fused together to form heavier nuclei. The heavy elements were then spewed out into space during either the cataclysm of a supernova (the explosion of a massive star) or the death of a red giant, the kind of star the sun will become in about five billion years. The cycle then began anew with the birth of the second generation star that was richer in its composition of elements.

DESCRIBE FACTS THAT DON'T FIT

As successful as this theory is, however, it cannot explain the existence of three light elements: lithium, beryllium, and boron.

STATE PROBLEM

How, then, were the three elements formed?[19]

The nuclei of these three elements, which contain three, four, and five protons respectively, are extremely fragile and would rapidly disintegrate in the hot, dense and violent interior of most stars. In fact, any lithium, beryllium and boron initially present in the core of a newly formed star would actually be destroyed as the star contracts and heats up.

WHY IS THIS PROBLEM NEW OR DISTINCTIVE?

At this point in your paper, you are ready to place the research problem in proper perspective. If you are writing for a specialized audience, you probably don't need to define why your work is important in larger terms. But even so, you should not hesitate to explain the significance of your work within the narrow domain of your specialty. The most direct way to describe the significance of the problem is to explain what the consequences of solving it would be.

Answer the Question in Both Specific and General Terms.

The following examples answer the questions posed on page 93.

- Because if ras p21 mediates insulin action, then we have another clue in the puzzle of diabetes, which in turn might lead to a cure.
- Because if white dwarves have planets, that explains the erratic quality of their orbit, might portray the future of our own planet, and might suggest why there are so many planets in the galaxy.
- Because knowing their migratory patterns would explain other data about populations of this bird, leading to a better picture of the health of the species.
- Knowing when retinal ganglia form in the human fetus may lead us to understand, and eventually prevent, certain congenital eye deformities.
- If a slower-beating heart prevents artherosclerosis, then perhaps we should intervene with drug therapy in high-risk artherosclerosis cases.
- If La_2CuO_4 possesses antiferromagnetism, it might lead to a new source of superconductivity.

- If we know what causes the disruption on the late Quaternary sediment cover on the continental slope off New Jersey, then we will have both a different picture of how geological forces work on this area and a better explanation of how sedimentation of pollutants affect the ocean floor.

In some cases, the import of a question is extremely specific and discipline-bound. Are you simply testing or seeking confirmation of someone else's hypothesis? For instance, in the paper about Quaternary sedimentation off the Jersey shore, the authors directly confront a statement made by other geologists:

Our data, however, do not support the proposal that the area has functioned largely as a derelict landscape, receiving a mantle of . . . sediments but lacking other, more active processes for at least 20,000 years.[20]

Include Nonscientific Contexts if They Have Influenced the Interpretation of Scientific Results or Motivated the Research Project.

For instance, in the article about lithium, beryllium and boron on page 94, the authors merely generalize about the importance of their subject:

The question has long baffled researchers.

Although curiosity is a sufficient motivator in its own right for science, this is not really as satisfactory as it could have been. One is still left wondering, so what? To find the importance of the question, you have to read through the paper to paragraphs near the conclusion. The authors could have included these sentences in the introduction instead.

What do the abundances of the light elements imply about the universe as a whole?. . . [They] can be used to infer the initial baryon density of the universe [which in turn can be used to calculate] Omega, the ration of the calculated density to the critical density of the universe: the minimum density for which the gravitational force would be sufficient to halt the present expansion of the universe. If Omega is less than 1, the universe is said to be open and will expand forever. If Omega is greater than 1, the universe is closed and it will eventually begin to contract. If Omega is equal to 1, the universe will continue to expand, but the rate of expansion will slow asymptotically.

When You Revise, Move the Context-Setting Information up Front.

One of the important parts of revising a paper is deciding which information comes in which order. The most common problem, one obviously apparent in the excerpt above, is that on the first pass through a paper, you often *write to discover what it is you want to say.* On the second pass through, you should move those insights up to the front to set the context for the information you are going to reveal in the rest of the paper.

CHECKLIST #12

WRITING THE INTRODUCTION

- ☐ Answer the question: *What is it I'm trying to discover or prove?*
- ☐ Answer the question: *Which kind of problem am I (are we) working on?*
- ☐ Pose the central question in terms of *why, when, how, where, what,* or *who?*
- ☐ Explain the theory or model.
- ☐ Describe what facts are already known that support or don't fit the theory.
- ☐ Elucidate where or why the match or mismatch occurs.
- ☐ State the problem in specific terms.
- ☐ Answer the question in both specific and general terms.
- ☐ Include nonscientific contexts if they have influenced the interpretation of scientific results or motivated the research project in the first place.
- ☐ When you revise your work, move the context-setting information up front.