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From Research to Manuscript

A Guide to Scientific Writing

Springer

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Introduction

Observations *Plus* Recipes

It has been said that science is the orderly collection of facts about the natural world. Scientists, however, are wary of using the word 'fact.' 'Fact' has the feeling of absoluteness and universality, whereas scientific observations are neither absolute nor universal.

For example, 'children have 20 deciduous [baby] teeth' is an observation about the real world, but scientists would not call it a fact. Some children have fewer deciduous teeth, and some have more. Even those children who have exactly 20 deciduous teeth use the full set during only a part of their childhood. When they are babies and toddlers, children have less than 20 visible teeth, and as they grow older, children begin to loose their deciduous teeth, which are then replaced by permanent teeth.

'Children have 20 deciduous [baby] teeth' is not even a complete scientific statement. For one thing, the statement 'children have 20 deciduous teeth' does not tell us what we mean by 'teeth.' When we say "teeth," do we mean only those that can seen be with the unaided eye, or do we also include the hidden, unerupted teeth?

An observation such as 'children have 20 deciduous teeth' is not a fact, and, by itself, it is not acceptable as a scientific statement until its terms are explained: scientifically, 'children have 20 deciduous teeth' must be accompanied by definitions and qualifiers. The standard way to put science into a statement is to define the statement's meaning operationally. Instead of attempting a purely verbal definition of 'teeth,' for instance, scientists define it by the procedure—the recipe—that has been used when making the observations about teeth.

In science, 'children have 20 deciduous teeth' is neither universal nor abstract. It is a record of the result of following a specific recipe, and the statement is scientific only when we include the recipe that was used. For 'children have 20 deciduous teeth,' one appropriate recipe would be: "I looked in the mouths of 25 five-year-old boys and 25 five-year-old girls in the Garden Day Nursery School in Cleveland, OH, on Monday, May 24, 2008, and I found that 23 of the boys and 25 of the girls had 20 visible teeth."

A meaningful scientific statement includes an observation and its recipe, and the standard form for recording meaningful scientific statements is the scientific research paper.

Writing a Scientific Research Paper

Science is the orderly collection of scientific records—i.e., observations about the natural world made via well-defined procedures—and scientific records are archived in a standardized form, the scientific research paper. A research project has not contributed to science until its results have been reported in a standard paper, the observations in which are accompanied by complete recipes. Therefore, to be a contributing scientist, you must write scientific papers.

This book contains my advice and thoughts about writing a scientific research paper. My basic hard-won realization is that writing a good scientific paper takes time. On the other hand, I have found that the writing will seem endless if you begin with the title and slog straight through to the last reference. This approach is difficult, wearing, and inefficient. There is a much more effective way to write.

I suggest that you write your paper from the inside out. Begin with the all-important recipes, the *Materials and Methods*. Next, collect your data and draft the *Results*. As your experiments end, formulate the outlines of a *Discussion*. Then write a working *Conclusion*. Now, go back and write the historical context, the *Introduction*. Only after all else has been written and tidied up, will you have sufficient perspective to write the *Title* and the *Abstract*.

Throughout the writing, your tools and techniques will be the same. You should use precise words and, whenever possible, numbers. You should write direct sentences that follow a straight line from point A to point B. In addition, you should fill all sections of the stereotyped skeleton of a standard scientific paper.

Writing a paper should be an active part of your research. If you wait until your studies are finished before you begin to write, you will miss a powerful tool. Research is iterative—you do, you assess, and you redo, and writing a paper is a way for you to continually make the reassessments necessary for critical and perceptive research.

Your manuscript can even be a blueprint for your experiments. The empty skeleton of a scientific paper poses a set of research questions, and, as you fill in the skeleton, you automatically carry out an orderly analysis of your data and observations. Moreover, by setting new data into the draft of your paper, you can maintain perspective. You will filter out the shine of newness, as your results—even unusual results—are put into the context of your existing data and your full research plan.

As a scientist, you must write, and, as an experimentalist, writing while you work strengthens your research. Writing a paper can be an integral part of observational science.

Scientific Papers Used as Examples

In the text of this book, I rebuild and improve a paper that I wrote in 1985, entitled "Intensifier for Bodian Staining of Tissue Sections and Cell Cultures." I use this paper because it is brief, simple, and well known to me.

Just as a picture is worth a thousand words, an actual example of a well-written scientific paragraph is worth a dozen descriptions of one. To illustrate the craft of scientific writing, I have included excerpts from scientific papers far better than my own.

The excerpts are from articles across the range of scientific studies. For the most part, these papers are lean, logical, and cleanly written. They are examples of good science writing and they have been recommended to me by the editors of the journals in which they appeared. In the text, I refer to the papers by author(s) and date. Here are the full bibliographic citations:

- Abercrombie M, Heaysman JEM. 1954. Observations on the social behaviour of cells. II. "Monolayering" of fibroblasts. Exp Cell Res 6: 293–306.
- Augspurger NR, Scherer CS, Garrow TA, Baker DH. 2005. Dietary s-methylmethionine, a component of foods, has choline-sparing activity in chickens. J Nutr 135: 1712–1717
- Berg D, Siefker C, Becker G. 2001. Echogenicity of the substantia nigra in Parkinson's disease and its relation to clinical findings. J Neurol 248: 684–689.
- Bohm A, Piribauer M, Wimazal F, Geissler W, Gisslinger H, Knobl P, Jager U, Fonatsch C, Kyrle PA, Valent P, Lechner K, Sperr WR. 2005. High dose intermittent ARA-C (HiDAC) for consolidation of patients with de novo AML: a single center experience. Leukemia Res 29: 609–615.
- Borgens RB, Bohnert D, Duerstock B, Spomar D, Lee RC. 2004. Tri-block copolymer produces recovery from spinal cord injury. J Neurosci Res 76: 141–154.
- Fastovsky DE, Sheehan P. 2005. The extinction of the dinosaurs in North America. GSA Today 15: 4–10.
- Gapski R, Barr JL, Sarment DP, Layher MG, Socransky SS, Giannobile WV. 2004. Effect of systemic matrix metalloproteinase inhibition on periodontal wound repair: a proof of concept trial. J Periodontol 75: 441–452.
- Glaunsinger B, Ganem D. 2004. Highly selective escape from KSHV-mediated host mRNA shutoff and its implications for viral pathogenesis. J Exp Med 200: 391–398.
- Haseler LJ, Arcinue E, Danielsen, ER, Bluml S, Ross D. 1997. Evidence from Proton Magnetic Resonance Spectroscopy for a Metabolic Cascade of Neuronal Damage in Shaken Baby Syndrome. Pediatrics 99: 4–14.
- Jacobson C-O. 1959. The localization of the presumptive cerebral regions in the neural plate of the axolotl larva. J Embryol Exp Morph 7: 1–21.
- Kiekkas P, Poulopoulou M, Papahatzi A, Panagiotis S. 2005. Is postanesthesia care unit length of stay increased in hypothermic patients? AORN J 81:379–382, 385–392.
- Milner B, Taylor L, Sperry RW. 1968. Lateralized suppression of dichotically presented digits after commissural section in man. Science 161: 184–186.
- Paul DR, McSpadden SK. 1976. Diffusional release of a solute from a polymer matrix. J Membrane Sci 1: 33–48.
- Perez JF, Sanderson MJ. 2005. The frequency of calcium oscillations induced by 5-HT, ACH, and KCl determine the contraction of smooth muscle cells of intrapulmonary bronchioles. J Gen Physiol 125: 535–553.

Chapter 1

THE STANDARDS OF A SCIENTIFIC PAPER

1. A STEREOTYPED FORMAT

Research papers are the repositories of scientific observations plus the recipes used to make those observations.

Scientific papers have a stereotyped format:

- *Abstract*
- *Introduction*
- *Materials and Methods*
- *Results*
- *Discussion*
- *Conclusion*
- *References*

The exact section headings sometimes vary, but most scientific papers look pretty much the same from the outside. There are no novel constructions or inventive twists of the narrative. Instead, the framework is unchanging so that the content can be studied without distraction. The predictable form of a scientific paper, with its standard set of sections arranged in a stereotyped order, ensures that a reader knows what to expect and where to find specific types of information.

2. PRECISE LANGUAGE

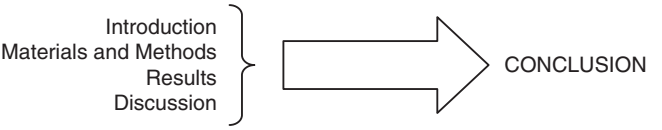
Within this stereotyped format, the language of a scientific paper aims to be clean, clear, and unemotional.

Much of the color of our everyday language derives from ill-defined, emotionally charged, ear-tickling images conjured up by sensuous words such as 'slovenly,' 'sibilant,' and 'sneaky.' Science, however, avoids colorful words.

The essential characteristic of scientific writing is clarity. Slippery words and vague phrases are confusing, and there is no place for ambiguity, arcane language, or froth in the archives of scientific records. In science, descriptions must be precise, recipes must be complete, data must be exact, logic must be transparent, and conclusions must be cleanly stated.

3. A SINGLE, CLEAR DIRECTION

Beyond a stereotyped format and transparent language, a scientific paper also needs clarity of direction. Your entire paper should point inexorably toward its *Conclusion*.



Therefore, as you write, point the way for your reader, and remove tangents and digressions. Keep a single theme at the fore. For example, if your *Conclusion* is about temperature, then temperature should be ever-present in your paper. 'Temperature' should be in the *Title*. The *Introduction* should tell how your predecessors wrote about temperature. The *Materials and Methods* section should detail the instruments that you used and the operations that you performed involving temperature. The *Results* section should include data about temperature, and the *Discussion* section should connect your data to the existing scientific literature about temperature.

4. REVIEWED AND MADE AVAILABLE TO OTHERS

Finally, a scientific paper should be accessible to others. Scientific journals are the traditional mechanisms for reviewing, disseminating, and preserving scientific papers, so submit your paper to a peer-reviewed journal. Having your paper reviewed by experts ensures that it can be understood and used by a broad scientific community. Then, having your paper preserved in a public forum ensures that the scientific community will have the opportunity to use it.