

## 6. Write in spirals

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write “Let 6 be a group.”?) A few other letters are almost frozen: many readers would feel offended if “ $n$ ” were used for a complex number, “ $\varepsilon$ ” for a positive integer, and “ $z$ ” for a topological space. (A mathematician’s nightmare is a sequence  $n_\varepsilon$  that tends to 0 as  $\varepsilon$  becomes infinite.)

Moral: do not increase the rigid frigidity. Think about the alphabet. It’s a nuisance, but it’s worth it. To save time and trouble later, think about the alphabet for an hour now; then start writing.

## 6. WRITE IN SPIRALS

The best way to start writing, perhaps the only way, is to write on the spiral plan. According to the spiral plan the chapters get written and re-written in the order 1, 2, 1, 2, 3, 1, 2, 3, 4, etc. You think you know how to write Chapter 1, but after you’ve done it and gone on to Chapter 2, you’ll realize that you could have done a better job on Chapter 2 if you had done Chapter 1 differently. There is no help for it but to go back, do Chapter 1 differently, do a better job on Chapter 2, and then dive into Chapter 3. And, of course, you know what will happen: Chapter 3 will show up the weaknesses of Chapters 1 and 2, and there is no help for it ... etc., etc., etc. It’s an obvious idea, and frequently an unavoidable one, but it may help a future author to know in advance what he’ll run into, and it may help him to know that the same phenomenon will occur not only for chapters, but for sections, for paragraphs, for sentences, and even for words.

The first step in the process of writing, rewriting, and re-rewriting, is writing. Given the subject, the audience, and the outline (and, don’t forget, the alphabet), start writing, and let nothing stop you. There is no better incentive for writing a good book than a bad book. Once you have a first draft in hand, spiral-written, based on a subject, aimed at an audience, and backed by as detailed an outline as you could scrape together, then your book is more than half done.

The spiral plan accounts for most of the rewriting and re-rewriting that a book involves (most, but not all). In the first draft of each chapter I recommend that you spill your heart, write quickly, violate all rules, write with hate or with pride, be snide, be confused, be “funny” if you must, be unclear, be ungrammatical—just keep on writing. When you come to rewrite, however, and however often that may be necessary, do not edit but rewrite. It is tempting to use a red pencil to indicate insertions, deletions, and permutations, but in my experience it leads to catastrophic blunders. Against human impatience, and against the all too human partiality everyone

feels toward his own words, a red pencil is much too feeble a weapon. You are faced with a first draft that any reader except yourself would find all but unbearable; you must be merciless about changes of all kinds, and, especially, about wholesale omissions. Rewrite means write again—every word.

I do not literally mean that, in a 10-chapter book, Chapter 1 should be written ten times, but I do mean something like three or four. The chances are that Chapter 1 should be re-written, literally, as soon as Chapter 2 is finished, and, very likely, at least once again, somewhere after Chapter 4. With luck you'll have to write Chapter 9 only once.

The description of my own practice might indicate the total amount of rewriting that I am talking about. After a spiral-written first draft I usually rewrite the whole book, and then add the mechanical but indispensable reader's aids (such as a list of prerequisites, preface, index, and table of contents). Next, I rewrite again, this time on the typewriter, or, in any event, so neatly and beautifully that a mathematically untrained typist can use this version (the third in some sense) to prepare the "final" typescript with no trouble. The rewriting in this third version is minimal; it is usually confined to changes that affect one word only, or, in the worst case, one sentence. The third version is the first that others see. I ask friends to read it, my wife reads it, my students may read parts of it, and, best of all, an expert junior-grade, respectably paid to do a good job, reads it and is encouraged not to be polite in his criticisms. The changes that become necessary in the third version can, with good luck, be effected with a red pencil; with bad luck they will cause one third of the pages to be retyped. The "final" typescript is based on the edited third version, and, once it exists, it is read, reread, proofread, and reproofread. Approximately two years after it was started (two working years, which may be much more than two calendar years) the book is sent to the publisher. Then begins another kind of labor pain, but that is another story.

Archimedes taught us that a small quantity added to itself often enough becomes a large quantity (or, in proverbial terms, every little bit helps). When it comes to accomplishing the bulk of the world's work, and, in particular, when it comes to writing a book, I believe that the converse of Archimedes' teaching is also true: the only way to write a large book is to keep writing a small bit of it, steadily every day, with no exception, with no holiday. A good technique, to help the steadiness of your rate of production, is to stop each day by priming the pump for the next day. What will you begin with tomorrow? What is the content of the next section to be; what is its title? (I recommend that you find a possible short title for each section,

before or after it's written, even if you don't plan to print section titles. The purpose is to test how well the section is planned: if you cannot find a title, the reason may be that the section doesn't have a single unified subject.) Sometimes I write tomorrow's first sentence today; some authors begin today by revising and rewriting the last page or so of yesterday's work. In any case, end each work session on an up-beat; give your subconscious something solid to feed on between sessions. It's surprising how well you can fool yourself that way; the pump-priming technique is enough to overcome the natural human inertia against creative work.

## 7. ORGANIZE ALWAYS

Even if your original plan of organization was detailed and good (and especially if it was not), the all-important job of organizing the material does not stop when the writing starts; it goes on all the way through the writing and even after.

The spiral plan of writing goes hand in hand with the spiral plan of organization, a plan that is frequently (perhaps always) applicable to mathematical writing. It goes like this. Begin with whatever you have chosen as your basic concept—vector spaces, say—and do right by it: motivate it, define it, give examples, and give counterexamples. That's Section 1. In Section 2 introduce the first related concept that you propose to study—linear dependence, say—and do right by it: motivate it, define it, give examples, and give counterexamples, and then, this is the important point, review Section 1, as nearly completely as possible, from the point of view of Section 2. For instance: what examples of linearly dependent and independent sets are easily accessible within the very examples of vector spaces that Section 1 introduced? (Here, by the way, is another clear reason why the spiral plan of writing is necessary: you may think, in Section 2, of examples of linearly dependent and independent sets in vector spaces that you forgot to give as examples in Section 1.) In Section 3 introduce your next concept (of course just what that should be needs careful planning, and, more often, a fundamental change of mind that once again makes spiral writing the right procedure), and, after clearing it up in the customary manner, review Sections 1 and 2 from the point of view of the new concept. It works, it works like a charm. It is easy to do, it is fun to do, it is easy to read, and the reader is helped by the firm organizational scaffolding, even if he doesn't bother to examine it and see where the joins come and how they support one another.