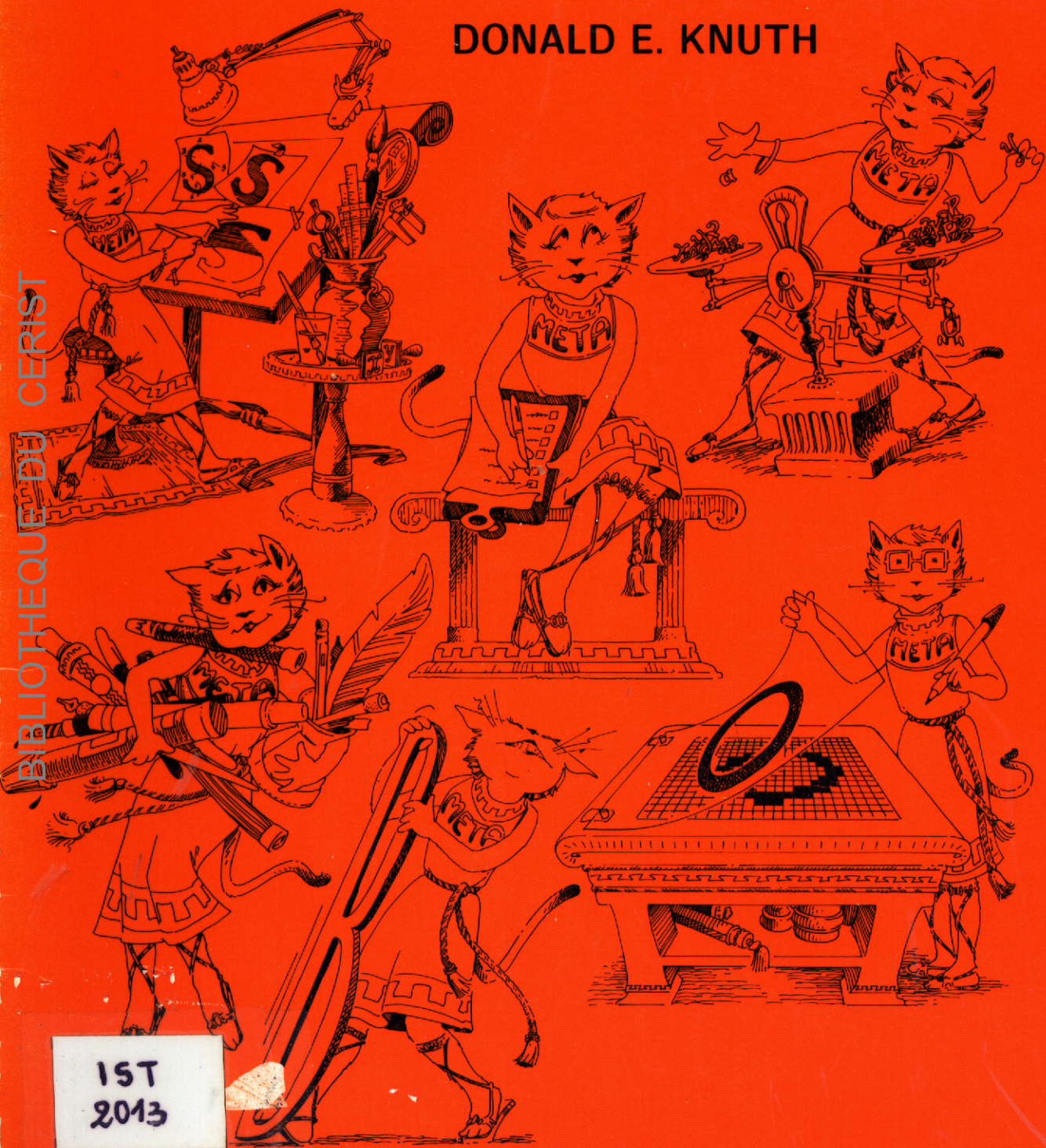


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The METAFONTbook

DONALD E. KNUTH

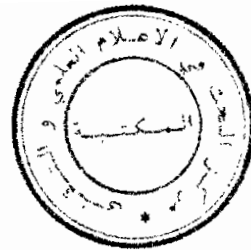
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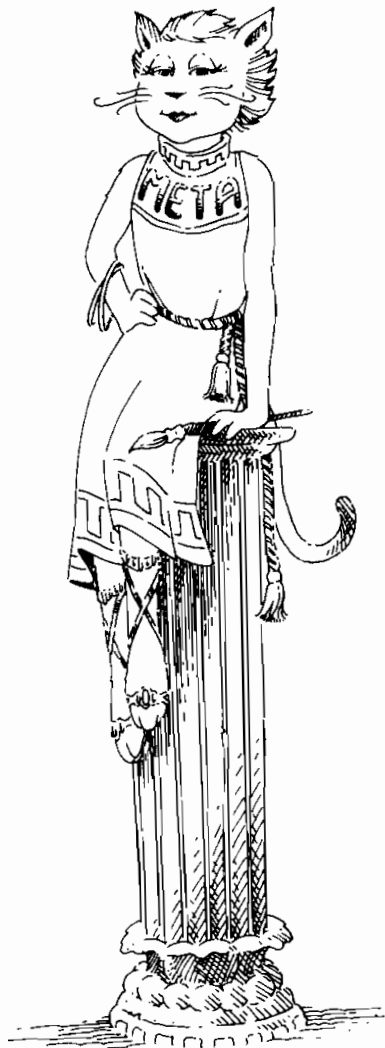
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The METAFONTbook

DONALD E. KNUTH *Stanford University*



BIBLIOTHEQUE DU CERIST



Illustrations by
DUANE BIBBY



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*To Hermann Zapf:
Whose strokes are the best*

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Preface

GENERATION OF LETTERFORMS by mathematical means was first tried in the fifteenth century; it became popular in the sixteenth and seventeenth centuries; and it was abandoned (for good reasons) during the eighteenth century. Perhaps the twentieth century will turn out to be the right time for this idea to make a comeback, now that mathematics has advanced and computers are able to do the calculations.

Modern printing equipment based on raster lines—in which metal “type” has been replaced by purely combinatorial patterns of zeroes and ones that specify the desired position of ink in a discrete way—makes mathematics and computer science increasingly relevant to printing. We now have the ability to give a completely precise definition of letter shapes that will produce essentially equivalent results on all raster-based machines. Moreover, the shapes can be defined in terms of variable parameters; computers can “draw” new fonts of characters in seconds, making it possible for designers to perform valuable experiments that were previously unthinkable.

METAFONT is a system for the design of alphabets suited to raster-based devices that print or display text. The characters that you are reading were all designed with METAFONT, in a completely precise way; and they were developed rather hastily by the author of the system, who is a rank amateur at such things. It seems clear that further work with METAFONT has the potential of producing typefaces of real beauty. This manual has been written for people who would like to help advance the art of mathematical type design.

A top-notch designer of typefaces needs to have an unusually good eye and a highly developed sensitivity to the nuances of shapes. A top-notch user of computer languages needs to have an unusual talent for abstract reasoning and a highly developed ability to express intuitive ideas in formal terms. Very few people have both of these unusual combinations of skills; hence the best products of METAFONT will probably be collaborative efforts between two people who complement each other’s abilities. Indeed, this situation isn’t very different from the way types have been created for many generations, except that the rôle of “punch-cutter” is now being played by skilled computer specialists instead of by skilled metalworkers.

A METAFONT user writes a “program” for each letter or symbol of a typeface. These programs are different from ordinary computer programs, because they are essentially *declarative* rather than imperative. In the METAFONT language you explain where the major components of a desired shape are

to be located, and how they relate to each other, but you don't have to work out the details of exactly where the lines cross, etc.: the computer takes over the work of solving equations as it deduces the consequences of your specifications. One of the advantages of METAFONT is that it provides a discipline according to which the principles of a particular alphabet design can be stated precisely. The underlying intelligence does not remain hidden in the mind of the designer; it is spelled out in the programs. Thus consistency can readily be obtained where consistency is desirable, and a font can readily be extended to new symbols that are compatible with the existing ones.

It would be nice if a system like METAFONT were to simplify the task of type design to the point where beautiful new alphabets could be created in a few hours. This, alas, is impossible; an enormous amount of subtlety lies behind the seemingly simple letter shapes that we see every day, and the designers of high-quality typefaces have done their work so well that we don't notice the underlying complexity. One of the disadvantages of METAFONT is that a person can easily use it to produce poor alphabets, cheaply and in great quantity. Let us hope that such experiments will have educational value as they reveal why the subtle tricks of the trade are important, but let us also hope that they will not cause bad workmanship to proliferate. Anybody can now produce a book in which all of the type is home-made, but a person or team of persons should expect to spend a year or more on the project if the type is actually supposed to look right. METAFONT won't put today's type designers out of work; on the contrary, it will tend to make them heroes and heroines, as more and more people come to appreciate their skills.

Although there is no royal road to type design, there are some things that can, in fact, be done well with METAFONT in an afternoon. Geometric designs are rather easy; and it doesn't take long to make modifications to letters or symbols that have previously been expressed in METAFONT form. Thus, although comparatively few users of METAFONT will have the courage to do an entire alphabet from scratch, there will be many who will enjoy customizing someone else's design.

This book is not a text about mathematics or about computers. But if you know the rudiments of those subjects (namely, contemporary high school mathematics, together with the knowledge of how to use the text editing or word processing facilities on your computing machine), you should be able to use METAFONT with little difficulty after reading what follows. Some parts

of the exposition in the text are more obscure than others, however, since the author has tried to satisfy experienced METAFONTers as well as beginners and casual users with a single manual. Therefore a special symbol has been used to warn about esoterica: When you see the sign



at the beginning of a paragraph, watch out for a “dangerous bend” in the train of thought—don’t read such a paragraph unless you need to. You will be able to use METAFONT reasonably well, even to design characters like the dangerous-bend symbol itself, without reading the fine print in such advanced sections.

Some of the paragraphs in this manual are so far out that they are rated



everything that was said about single dangerous-bend signs goes double for these. You should probably have at least a month’s experience with METAFONT before you attempt to fathom such doubly dangerous depths of the system; in fact, most people will never need to know METAFONT in this much detail, even if they use it every day. After all, it’s possible to fry an egg without knowing anything about biochemistry. Yet the whole story is here in case you’re curious. (About METAFONT, not eggs.)

The reason for such different levels of complexity is that people change as they grow accustomed to any powerful tool. When you first try to use METAFONT, you’ll find that some parts of it are very easy, while other things will take some getting used to. At first you’ll probably try to control the shapes too rigidly, by overspecifying data that has been copied from some other medium. But later, after you have begun to get a feeling for what the machine can do well, you’ll be a different person, and you’ll be willing to let METAFONT help contribute to your designs as they are being developed. As you gain more and more experience working with this unusual apprentice, your perspective will continue to change and you will run into different sorts of challenges. That’s the way it is with any powerful tool: There’s always more to learn, and there are always better ways to do what you’ve done before. At every stage in the development you’ll want a slightly different sort of manual. You may even want to write one yourself. By paying attention to the dangerous bend signs in this book you’ll be better able to focus on the level that interests you at a particular time.

Computer system manuals usually make dull reading, but take heart: This one contains JOKES every once in a while. You might actually enjoy reading it. (However, most of the jokes can only be appreciated properly if you understand a technical point that is being made— so read *carefully*.)

Another noteworthy characteristic of this book is that it doesn't always tell the truth. When certain concepts of METAFONT are introduced informally, general rules will be stated: afterwards you will find that the rules aren't strictly true. In general, the later chapters contain more reliable information than the earlier ones do. The author feels that this technique of deliberate lying will actually make it easier for you to learn the ideas. Once you understand a simple but false rule, it will not be hard to supplement that rule with its exceptions.

In order to help you internalize what you're reading, EXERCISES are sprinkled through this manual. It is generally intended that every reader should try every exercise, except for questions that appear in the "dangerous bend" areas. If you can't solve a problem, you can always look up the answer. But please, try first to solve it by yourself; then you'll learn more and you'll learn faster. Furthermore, if you think you do know the solution, you should turn to Appendix A and check it out, just to make sure.

WARNING: Type design can be hazardous to your other interests. Once you get hooked, you will develop intense feelings about letterforms: the medium will intrude on the messages that you read. And you will perpetually be thinking of improvements to the fonts that you see everywhere, especially those of your own design.

The METAFONT language described here has very little in common with the author's previous attempt at a language for alphabet design, because five years of experience with the old system has made it clear that a completely different approach is preferable. Both languages have been called METAFONT; but henceforth the old language should be called METAFONT79, and its use should rapidly fade away. Let's keep the name METAFONT for the language described here, since it is so much better, and since it will never change again.

I wish to thank the hundreds of people who have helped me to formulate this "definitive edition" of METAFONT, based on their experiences with preliminary versions of the system. In particular, John Hobby discovered many of

the algorithms that have made the new language possible. My work at Stanford has been generously supported by the National Science Foundation, the Office of Naval Research, the IBM Corporation, and the System Development Foundation. I also wish to thank the American Mathematical Society for its encouragement and for publishing the *TUGboat* newsletter (see Appendix J). Above all, I deeply thank my wife, Jill, for the inspiration, understanding, comfort, and support she has given me for more than 25 years, especially during the eight years that I have been working intensively on mathematical typography.

Stanford, California
September 1985

— D. E. K.

*It is hoped that Divine Justice may find
some suitable affliction for the malefactors
who invent variations upon the alphabet of our fathers. . . .
The type-founder, worthy mechanic, has asserted himself
with an overshadowing individuality,
defacing with his monstrous creations and revivals
every publication in the land.*

— AMBROSE BIERCE, *The Opinionator. Alphabètes* (1911)

*Can the new process yield a result that, say,
a Club of Bibliophiles would recognise as a work of art
comparable to the choice books they have in their cabinets?*

— STANLEY MORISON, *Typographic Design in Relation to
Photographic Composition* (1958)

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