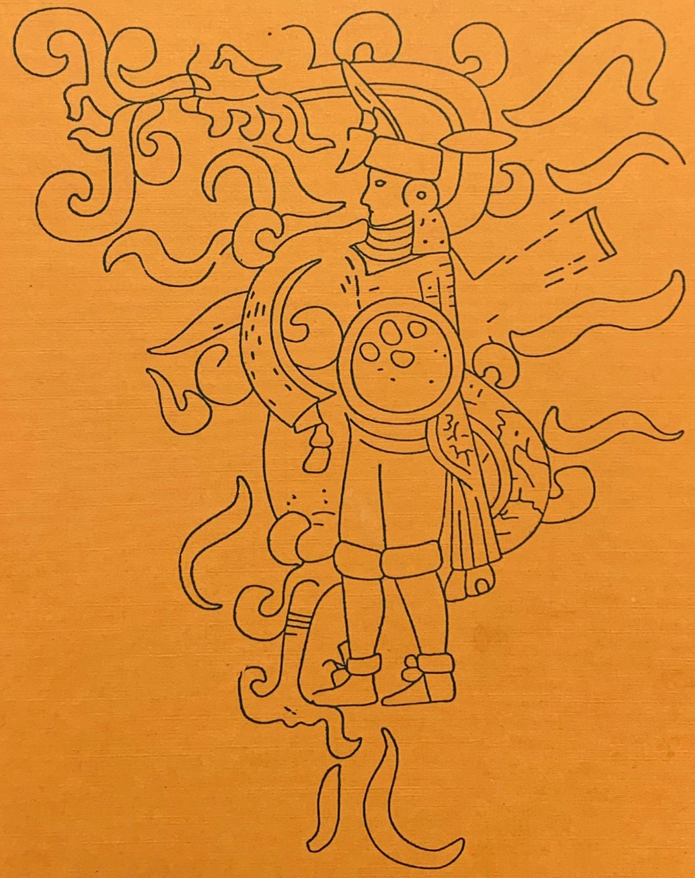

Philip Ording

I. VISIBLE LANGUAGE

VISIBLE LANGUAGE

The research journal concerned with all that is involved in our being literate
Volume XVI Number 1 Winter 1982



The covers show details from Mesoamerican paintings on the Temple of the Jaguars at Chichen Itza with representations of a cloud serpent. They are believed to be the name glyphs of the Toltec rulers, Quetzalcoatl and Mixcoatl. See David Kelley's article beginning on page 39.

The Concept of a Meta-Font

Donald E. Knuth

A single drawing of a single letter reveals only a small part of what was in the designer's mind when that letter was drawn. But when precise instructions are given about how to make such a drawing, the intelligence of that letter can be captured in a way that permits us to obtain an infinite variety of related letters from the same specification. Instead of merely describing a single letter, such instructions explain how that letter would change its shape if other parameters of the design were changed. Thus an entire font of letters and other symbols can be specified so that each character adapts itself to varying conditions in an appropriate way. Initial experiments with a precise language for pen motions suggest strongly that the font designer of the future should not simply design isolated alphabets; the challenge will be to explain exactly how each design should adapt itself gracefully to a wide range of changes in the specification. This paper gives examples of a meta-font and explains the changeable parameters in its design.

Some of Aristotle's philosophical writings were called *Metaphysics*, because they came *after* his *Physics*, in the conventional arrangement of his works. By the twentieth century, most people had forgotten the original meaning of Greek prefixes, so that 'meta-' was assumed to add a transcendent character to whatever it qualified. We now have metapsychology (the study of how the mind relates to its containing body), metamathematics (the study of mathematical reasoning), and metalinguistics (the study of how language relates to culture); a metamathematician proves metatheorems (theorems about theorems), and a computer scientist often works with metalanguages (languages for describing languages). Newly coined words beginning with 'meta-' generally reflect our contemporary inclination to view things from outside, at

Visible Language, XVI 1 (Winter 1982), 3-27.
Author's address: Department of Computer Science, Stanford University, Stanford CA 94305.

VISIBLE LANGUAGE Volume XVI Number 4 Autumn 1982

Editor's note

Visible Language has a long history of special interest in computer-assisted design of letterforms. A few months after the first issue appeared in January 1967 I walked across the street from my office to the Department of Computer Science at Case Western Reserve University to see if I could arouse any interest in research on the design of typefaces. Graduate student Paul Vargo was indeed interested and under the direction of his faculty advisor, Harry Mergler, produced as his doctoral dissertation the first computer system for parametric letter design. The results were published in this journal (then *The Journal of Typographic Research)* the following year. It was an introductory study and handicapped by equipment limitations of the mid-1960s. In essence, it was an idea whose time had not yet come.

Fourteen years later — in early 1981 — I walked across the street again to meet and talk with Donald Knuth about Meta-Font. By coincidence, Knuth is an alumnus of Case Western Reserve University but was graduated years before Paul Vargo and unaware of his research. I suggested to Knuth that when he was ready to present his ideas to the graphic ign audience, he should use the pages of *Visible Language*. He agreed, "The Concept of a Meta-Font" was published earlier this year. occurred to the editors that it might be valuable to follow-up publi- on with a survey of those most knowledgeable and most experienced type font generation, asking for reactions and ideas on the meta-font oncept and/or on computer-assisted letter design in general.

The article/response by Douglas R. Hofstadter which begins on the opposite page is followed by letters from type designers, graphic designers, and others in the graphic arts field — with a final response from Donald Knuth. The editors thank all of the respondents for their thoughtful replies. The lack of concensus at this stage of developing the meta-font concept is most heartening!

A few copies of the issues containing Knuth's article (Winter 1982) and the Mergler/Vargo article (Autumn 1968) are still available. To order, see the previous page.

M.E.W.

Metafont, Metamathematics, and Metaphysics

Comments on Donald Knuth's Article "The Concept of a Meta-Font"

Douglas R. Hofstadter

It is argued that readers are likely to carry away from Donald Knuth's article "The Concept of a Meta-Font" a falsely optimistic view of the extent to which the design of typefaces and letterforms can be mechanized through an approach depending on describing letterforms by specifying the settings of a large number of parameters. Through a comparison to mathematical logic, it is argued that no such set of parameters can capture the essence of any semantic category. Some different ways of thinking about the problem of the "spirit" residing behind any letterform are suggested, connecting to current research issues in the field of artificial intelligence.

The "Mathematization of Categories" and Metamathematics

Donald Knuth has spent the past several years working on a system allowing him to control many aspects of the design of his forthcoming books–from the typesetting and layout down to the very shapes of the letters! Never has an author had anything remotely like this power to control the final appearance of his or her work. Knuth's TEX typesetting system has become well-known and available in many countries around the world. By contrast, his Metafont system for designing families of typefaces has not become as well known or as available.

In his article "The Concept of a Meta-font" [Knuth 82], Knuth sets forth for the first time the underlying philosophy of Metafont, as well as some of its products. Not only is the concept exciting and clearly well executed, but in my opinion the article is charmingly written as well. However, despite my overall enthusiasm for Knuth's idea and article, there are some points in it that I feel might be taken wrongly by many readers, and since they are points that touch close to my deepest interests in artificial intelligence and esthetic theory, I felt compelled to make some comments to clarify certain important issues raised by "The Concept of a Meta-font".

Although his article is primarily about letterforms, not philosophy, Knuth holds out in it a philosophically tantalizing prospect for us: that with the arrival of computers, we can now approach the vision of a unification of all typefaces. This can be broken down into two ideas: (1) that underneath all "A" 's there is just one grand, ultimate abstraction

Visible Language, XVI 4 (Autumn 1982), pp. 309-338.
Author's address: Computer Science Department, Indiana University, Bloomington, IN 47405.

visible language

Volume XVII Number 4 Autumn 1983

The quarterly concerned with all that is involved in our being literate

Is Roman Type an Open-Ended System? A Response to Douglas Hofstadter

I believe that Douglas Hofstadter (1982) is unfair in his critique of Donald Knuth's "metafont" article (Knuth 1982). I do not dispute Hofstadter's view that the production of new examples of semantic categories such as "chair" or "waltz" is often a creative act, in a sense which implies that the extension of such categories is not recursively enumerable. This is a point of view which I have often (e.g., Sampson 1979, ch. 3) been at pains to argue myself. (It seems unhelpful to invoke Gödel's theorem in this connexion; the issue is not primarily a mathematical one, and Wittgenstein's analysis of the word *game* in the *Philosophical Investigations* [Wittgenstein 1953, §66ff.] is surely a clearer and more persuasive statement of the case than any discussion in terms of formal logic. But that is by the way.) Even if we accept the existence of many non-enumerable categories, though, we must surely accept that there are also many categories which *are* rigorously enumerable; for instance the class of *colours* has infinitely many members (because wavelength, saturation, and so on, are continuous variables), but all those members are located within a logical space which has fixed boundaries that depend on the physiology of human vision and the properties of light—no one will ever be able to create a new range of colours different in kind from the ones we know already. Human life involves both open-ended categories and closed categories, and in many cases it is very hard to say whether a given intuitively-familiar category is open-ended or closed. Is the category "sentence of the English language" closed or open-ended? Academic linguists have different views on the question. Hofstadter writes as if Knuth assumes an obviously open-ended category to be closed; but I cannot see that Hofstadter has demonstrated this.

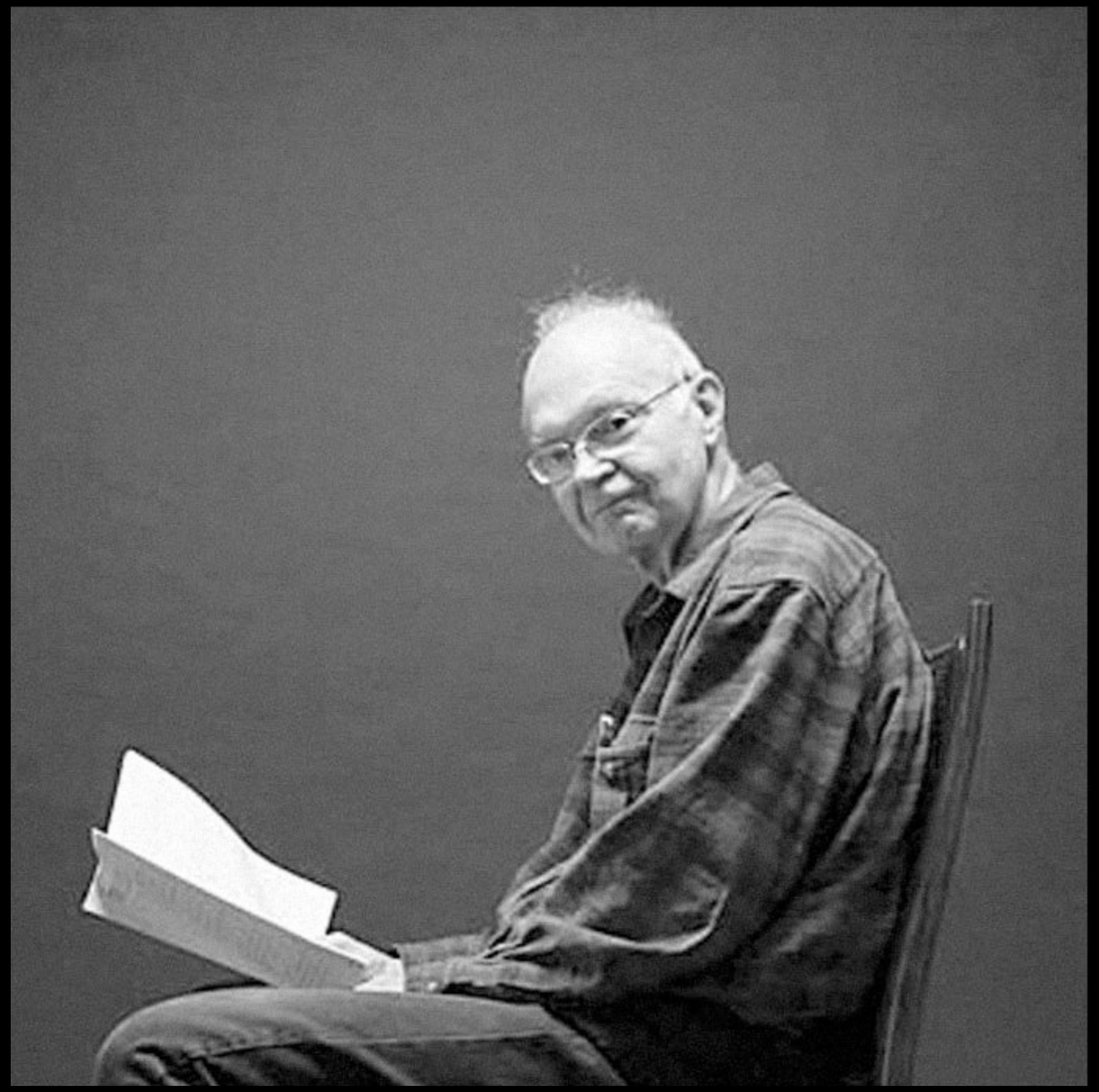
The kernel of Hofstadter's critique relates to Knuth's throwaway remark about a hypothetical font that is "one fourth of the way between Baskervill and Helvetica." According to Hofstadter, Knuth's belief that this concept sense commits Knuth to the idea that one could in principle define a "meta a finite set of typographical variables which generates all actual Roman-al fonts (in the sense that any such font would correspond to some particul choice of value for each variable) and n hat is not a Roman font Hofstadter suggests the implausibility lustrating a very dive of upper-case As (his Figure 1).

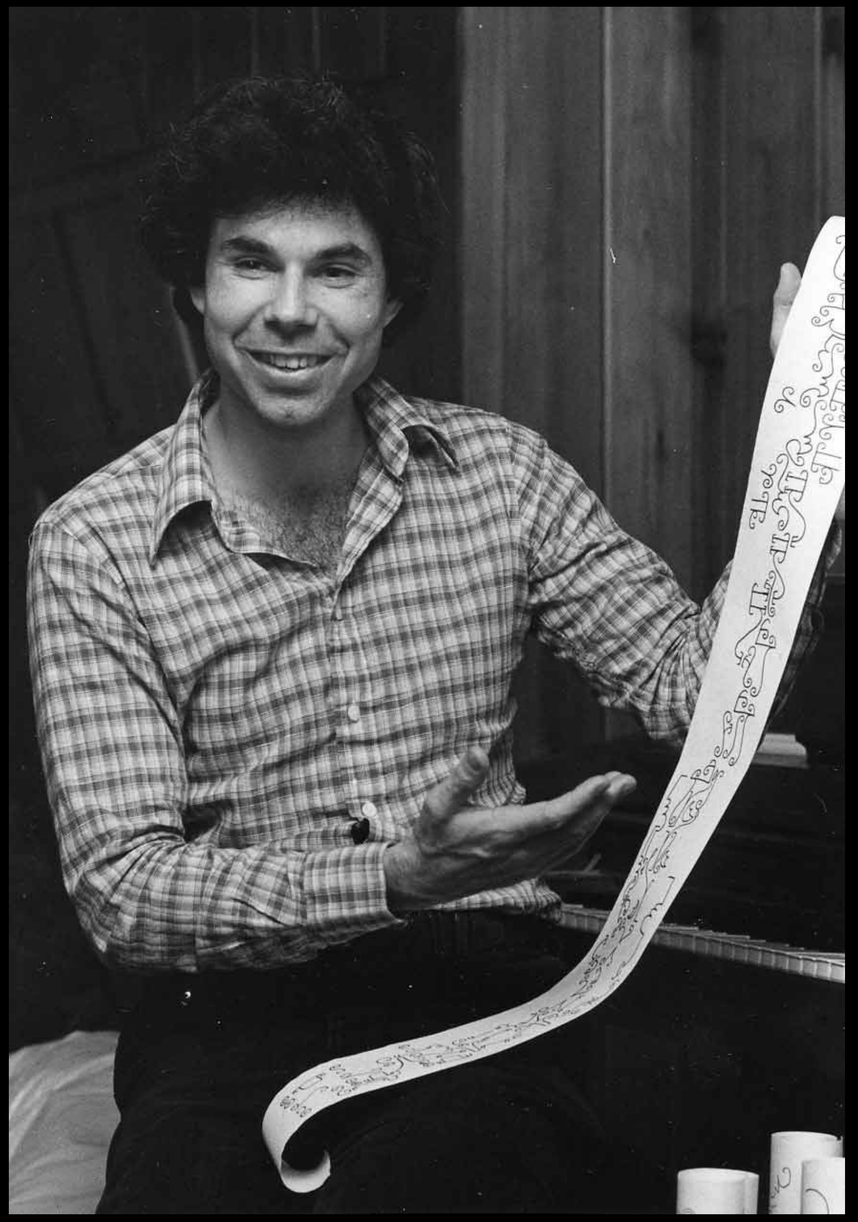
But, although Knuth's remark was so n the context of that it seems unreasonable of Hofstadter tress on it, it v fact as indefensible as Hofstadter makes it erville and He

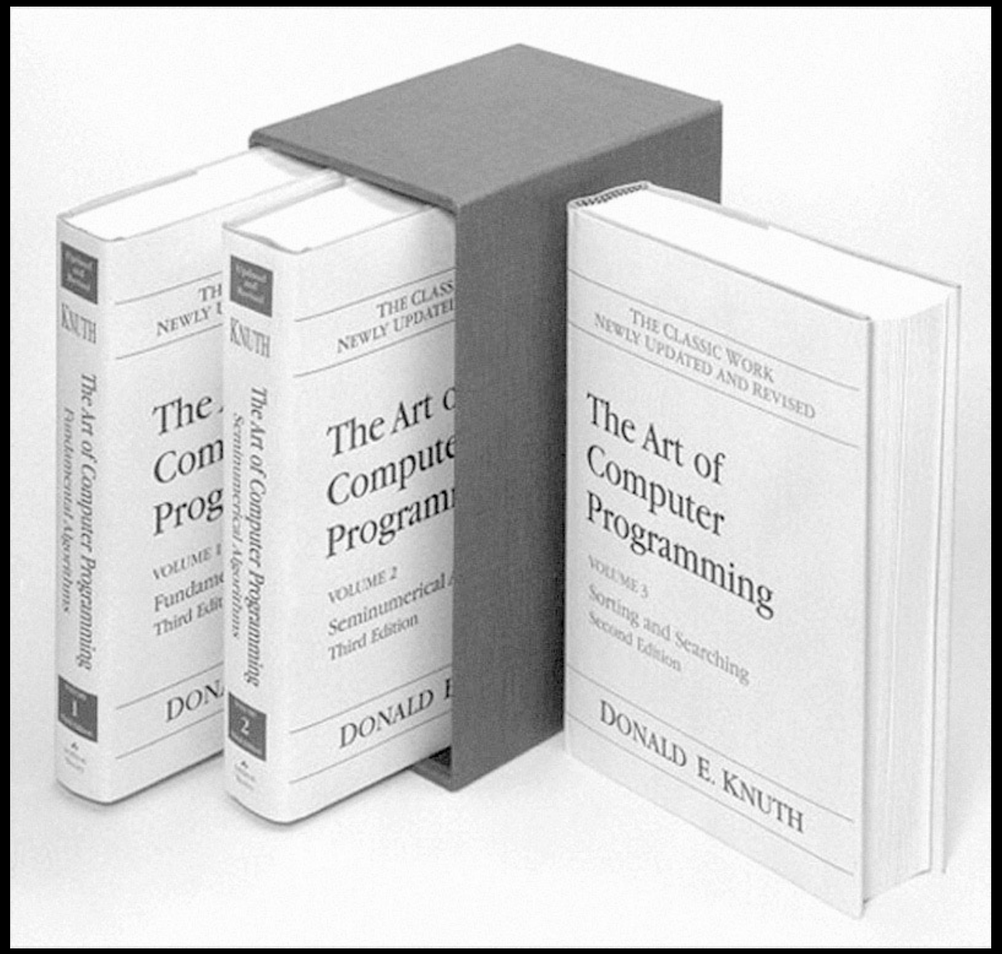
both book faces, rather than faces designed exclusively for display. On the other hand, the 56 As of Hofstadter's Figure 1 are all drawn from display faces. (Old English, E2 in Figure 1, has not been used as a book face for several centuries, and arguably is as distinct from the Roman alphabet in the normal sense as the Greek alphabet is—we do not classify it as a separate alphabet because we use it to write our own language.) It is much less obvious that the class of book faces is open-ended than that the class of display faces is.

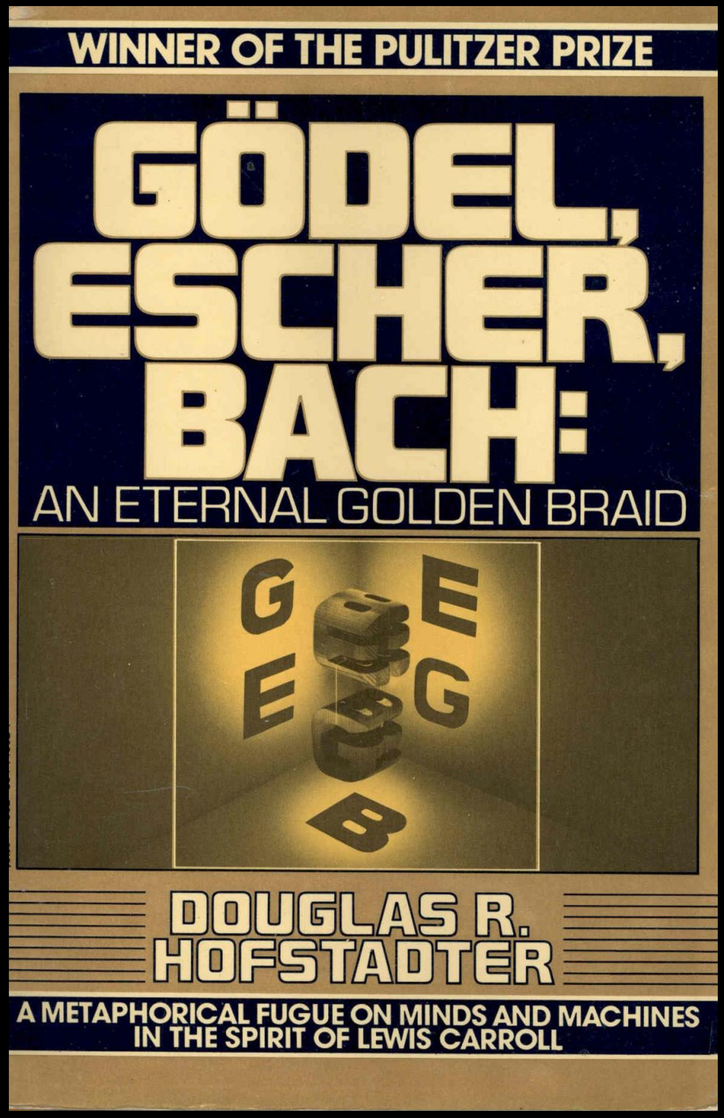
In the design of a display face the aim of instantiating the various Roman letters is often subordinate to the aim of creating a particular visual effect. Sometimes the designer goes so far to achieve the second aim that he fails to achieve the first. When a concept is open-ended, there will often be room for doubt about whether a given marginal instance falls within its extension or not (that is why, in the law, we have the institution of "test cases" as a mechanism for reaching society-wide agreement about whether given actions fall inside or outside the open-ended category of "illegal acts"). Hofstadter says that a metafont would need to generate all the letter-shapes in his Figure 1; but I believe that some of them are not in fact examples of the letter A. I would make that claim for D5, which is one of the variants offered for A in Cathedral; for E8, which I have not succeeded in identifying; and, less confidently, for C4 (Block Up) and A8 (Stop). Just as, being a native speaker of English, I judge that the poet E.E. Cummings's line *Anyone lived in a little how town* is not an English sentence (whatever other virtues it may have), so, as a "native reader" of the Roman alphabet, I judge that the shape D5 is not a letter A. An inscription in letters all of which were as distorted as D5 could not be read by an otherwise compe r, unless he learned the distorted letters as one can learn the Gree rew alphabet. (Most of the other letter-shapes in Cathedral are relat , so in practice D5 would be understood from context.)

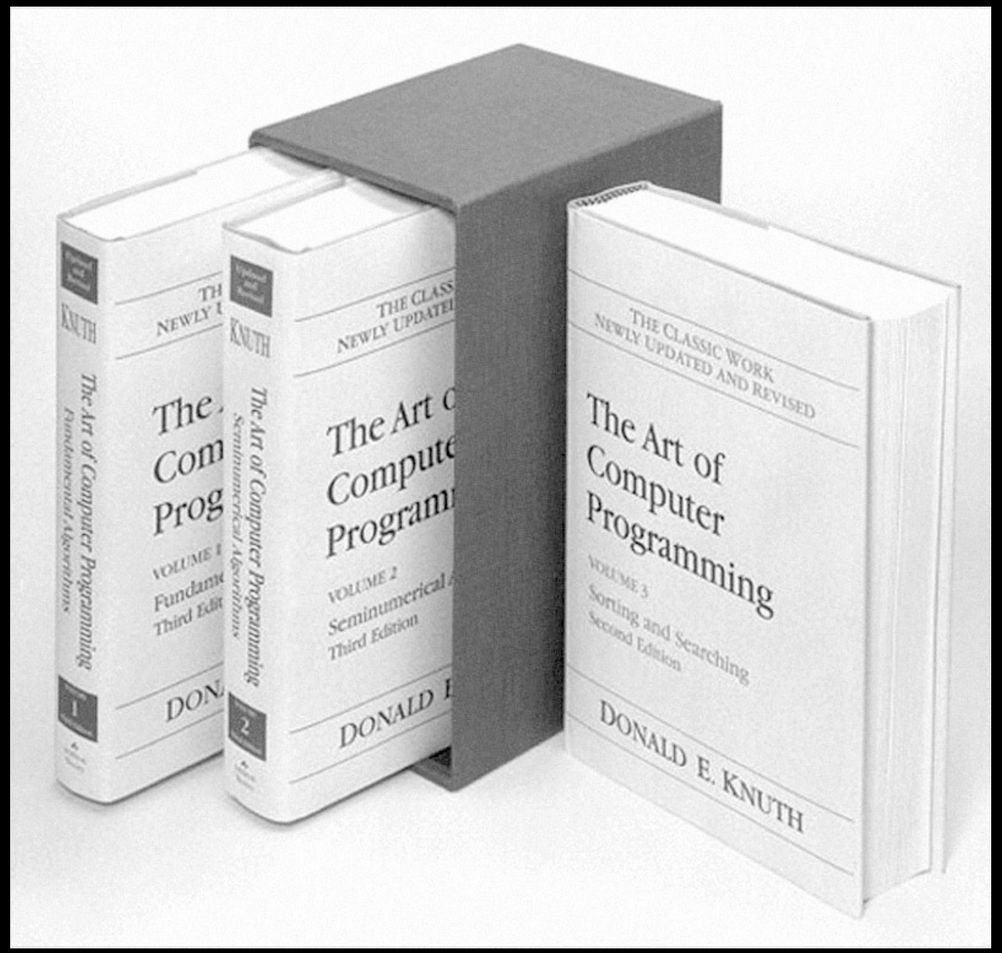
Re of designing a metafont to generate all and only the possible ev ght not have to cope with everything in Hofstadter's Figure 1, ed display as w ook faces. Still, I guess that the range of would in fact l ded even if pathological items like D5 d. But if we ask to book faces (which are the only sed by Knut en-endedness of the range really does estionable. 323) denies that this restriction affects his "more co rs . . . [o]ne simply has to look at a finer and all th issues reappear." Do they? ly argum gives for this is the difficulty of "parametrizing" trast bet dots of Baskerville i, j and the square dots in tica, and s of Q in the two faces. But Hofstadter concedes it is not that these problems could be solved. Furthermore seems to r of such points, where two faces differ with espect to an individual letter in a way that appears not to be

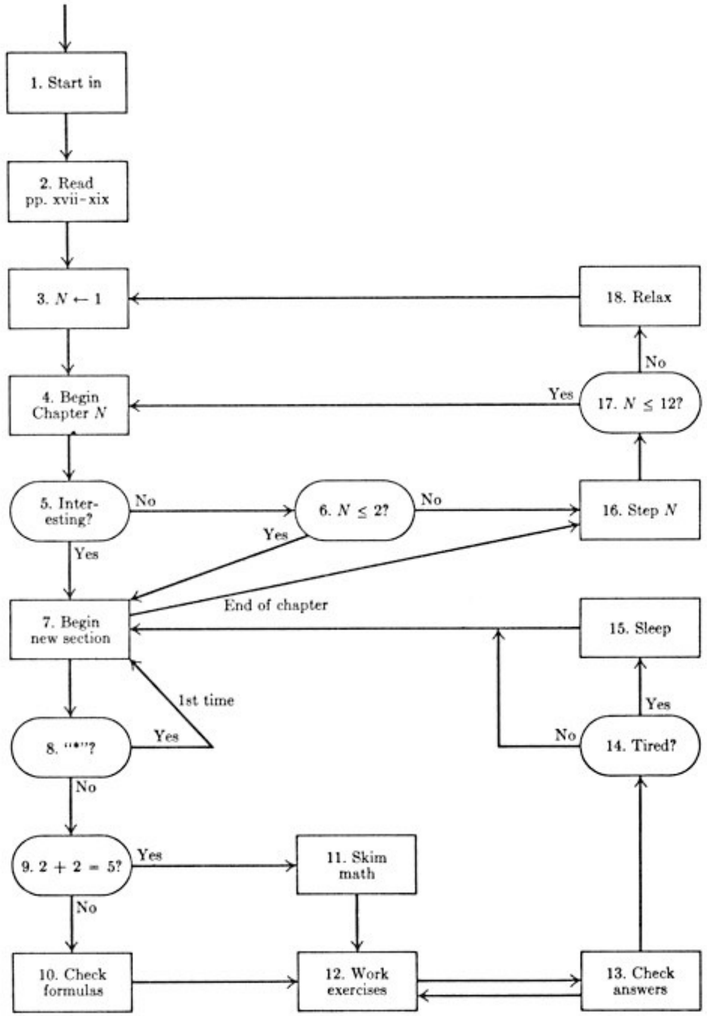





KNUTH
The Art of Computer Programming
Fundamental Algorithms
VOLUME 1
Third Edition
DONALD E. KNUTH
KNUTH
The Art of Computer Programming
Seminumerical Algorithms
VOLUME 2
Third Edition
DONALD E. KNUTH
THE CLASSIC WORK
NEWLY UPDATED AND REVISED
The Art of Computer Programming
VOLUME 3
Sorting and Searching
Second Edition
DONALD E. KNUTH


WINNER OF THE PULITZER PRIZE
GÖDEL, ESCHER, BACH:
AN ETERNAL GOLDEN BRAID
G E
E G
B B
DOUGLAS R. HOFSTADTER
A METAPHORICAL FUGUE ON MINDS AND MACHINES
IN THE SPIRIT OF LEWIS CARROLL


KNUTH
The Art of Computer Programming
Fundamental Algorithms
Third Edition
1
KNUTH
The Art of Computer Programming
Seminumerical Algorithms
Third Edition
2
THE CLASSIC WORK
NEWLY UPDATED AND REVISED
The Art of
Computer
Programming
VOLUME 3
Sorting and Searching
Second Edition
DONALD E. KNUTH



Flow chart for reading this set of books.

first time. That experience changed my life. Already on February 8 I began to talk to colleagues about the possibilities of using such machines to typeset my own books.

My diary of 1977 says nothing more about typographic matters until March 30; on that day, however, the die was cast.

30 Mar: Galley proofs for vol. 2 finally arrive, they look awful... I decide I have to solve the problem myself. typographically
Seder supper at church, is a bright spot in dull week.

I had to devote the month of April to finishing the other projects I had started. But by the beginning of May I had decided to create a program called 'TEX', and I was gearing up to embark on a new adventure.

2 May: Section 7.1 finished tonight at 1:00 a.m. — Hurray!

3 May: To San Jose with Jill, looking at church records from town near Heidelberg, figuring out old German handwriting

BULLETIN (New Series) OF THE
AMERICAN MATHEMATICAL SOCIETY
Volume 1, Number 2, March 1979

MATHEMATICAL TYPOGRAPHY

BY DONALD E. KNUTH

Dedicated to George Pólya on his 90th birthday

ABSTRACT. Mathematics books and journals do not look as beautiful as they used to. It is not that their mathematical content is unsatisfactory, rather that the old and well-developed traditions of typesetting have become too expensive. Fortunately, it now appears that mathematics itself can be used to solve this problem.

A first step in the solution is to devise a method for unambiguously specifying mathematical manuscripts in such a way that they can easily be manipulated by machines. Such languages, when properly designed, can be learned quickly by authors and their typists, yet manuscripts in this form will lead directly to high quality plates for the printer with little or no human intervention.

A second step in the solution makes use of classical mathematics to design the shapes of the letters and symbols themselves. It is possible to give a rigorous definition of the exact shape of the letter "a", for example, in such a way that infinitely many styles (bold, extended, sans-serif, italic, etc.) are obtained from a single definition by changing only a few parameters. When the same is done for the other letters and symbols, we obtain a mathematical definition of type fonts, a definition that can be used on all machines both now and in the future. The main significance of this approach is that new symbols can readily be added in such a way that they are automatically consistent with the old ones.

Of course it is necessary that the mathematically-defined letters be beautiful according to traditional notions of aesthetics. Given a sequence of points in the plane, what is the most pleasing curve that connects them? This question leads to interesting mathematics, and one solution based on a novel family of spline curves has produced excellent fonts of type in the author's preliminary experiments. We may conclude that a mathematical approach to the design of alphabets does not eliminate the artists who have been doing the job for so many years; on the contrary, it gives them an exciting new medium to work with.

I will be speaking today about work in progress, instead of completed research; this was not my original intention when I chose the subject of this lecture, but the fact is I couldn't get my computer programs working in time. Fortunately it is just as well that I don't have a finished product to describe to you today, because research in mathematics is generally much more interesting while you're doing it than after it's all done. I will try therefore to convey

Josiah Willard Gibbs Lecture, given under the auspices of the American Mathematical Society, January 4, 1978; received by the editors February 10, 1978.

The research was supported in part by National Science Foundation grant MCS72-03752 A03, and by the Office of Naval Research contract N00014-76-C-0330.
0002-9904/79/0000-0117/$10.00


TEX

An Example Document

Leslie Lamport

January 21, 1994

This is an example input file. Comparing it with the output it generates can show you how to produce a simple document of your own.

1 Ordinary Text

The ends of words and sentences are marked by spaces. It doesn't matter how many spaces you type; one is as good as 100. The end of a line counts as a space.

One or more blank lines denote the end of a paragraph.

Since any number of consecutive spaces are treated like a single one, the formatting of the input file makes no difference to LaTeX, but it makes a difference to you. When you use LaTeX, making your input file as easy to read as possible will be a great help as you write your document and when you change it. This sample file shows how you can add comments to your own input file.

Because printing is different from typewriting, there are a number of things that you have to do differently when preparing an input file than if you were just typing the document directly. Quotation marks like "this" have to be handled specially, as do quotes within quotes: "'this' is what I just wrote, not 'that'".

Footnotes[1] pose no problem.

LaTeX is good at typesetting mathematical formulas like $x - 3y + z = 7$ or $a_1 > x^{2n} + y^{2n} > x'$ or $(A, B) = \sum_i a_i b_i$. The spaces you type in a formula are ignored. Remember that a letter like x is a formula when it denotes a mathematical symbol, and it should be typed as one.

Mathematical formulas may also be displayed. A displayed formula is one-line long; multiline formulas require special formatting instructions.

$$(\Gamma, \psi') = x'' + y^2 + z_i^n$$

Don't start a paragraph with a displayed equation, nor make one a paragraph by itself.

Dashes come in three sizes: an intra-word dash, a medium dash for number ranges like 1–2, and a punctuation dash—like this.

[1] This is an example of a footnote.

```
% This is a sample LaTeX input file.  (Version of 12 August 2004.)
%
% A '%' character causes TeX to ignore all remaining text on the line,
% and is used for comments like this one.

\documentclass{article}      % Specifies the document class

                             % The preamble begins here.
\title{An Example Document}  % Declares the document's title.
\author{Leslie Lamport}      % Declares the author's name.
\date{January 21, 1994}      % Deleting this command produces today's date.

\newcommand{\ip}[2]{(#1, #2)}
                             % Defines \ip{arg1}{arg2} to mean
                             % (arg1, arg2).

%\newcommand{\ip}[2]{\langle #1 | #2\rangle}
                             % This is an alternative definition of
                             % \ip that is commented out.

\begin{document}             % End of preamble and beginning of text.

\maketitle                   % Produces the title.

This is an example input file.  Comparing it with
the output it generates can show you how to
produce a simple document of your own.

\section{Ordinary Text}      % Produces section heading.  Lower-level
                             % sections are begun with similar
                             % \subsection and \subsubsection commands.

The ends  of words and sentences are marked
  by   spaces. It  doesn't matter how many
spaces    you type; one is as good as 100.  The
end of   a line counts as a space.

One   or more   blank lines denote the  end
of  a paragraph.

Since any number of consecutive spaces are treated
like a single one, the formatting of the input
file makes no difference to
      \LaTeX,                % The \LaTeX command generates the LaTeX logo.
but it makes a difference to you.  When you use
\LaTeX, making your input file as easy to read
as possible will be a great help as you write
your document and when you change it.  This sample
file shows how you can add comments to your own input
file.

Because printing is different from typewriting,
there are a number of things that you have to do
differently when preparing an input file than if
you were just typing the document directly.
Quotation marks like
       ``this''
have to be handled specially, as do quotes within
quotes:
       ``\,`this'            % \, separates the double and single quote.
       is what I just
       wrote, not  `that'\,''.
```

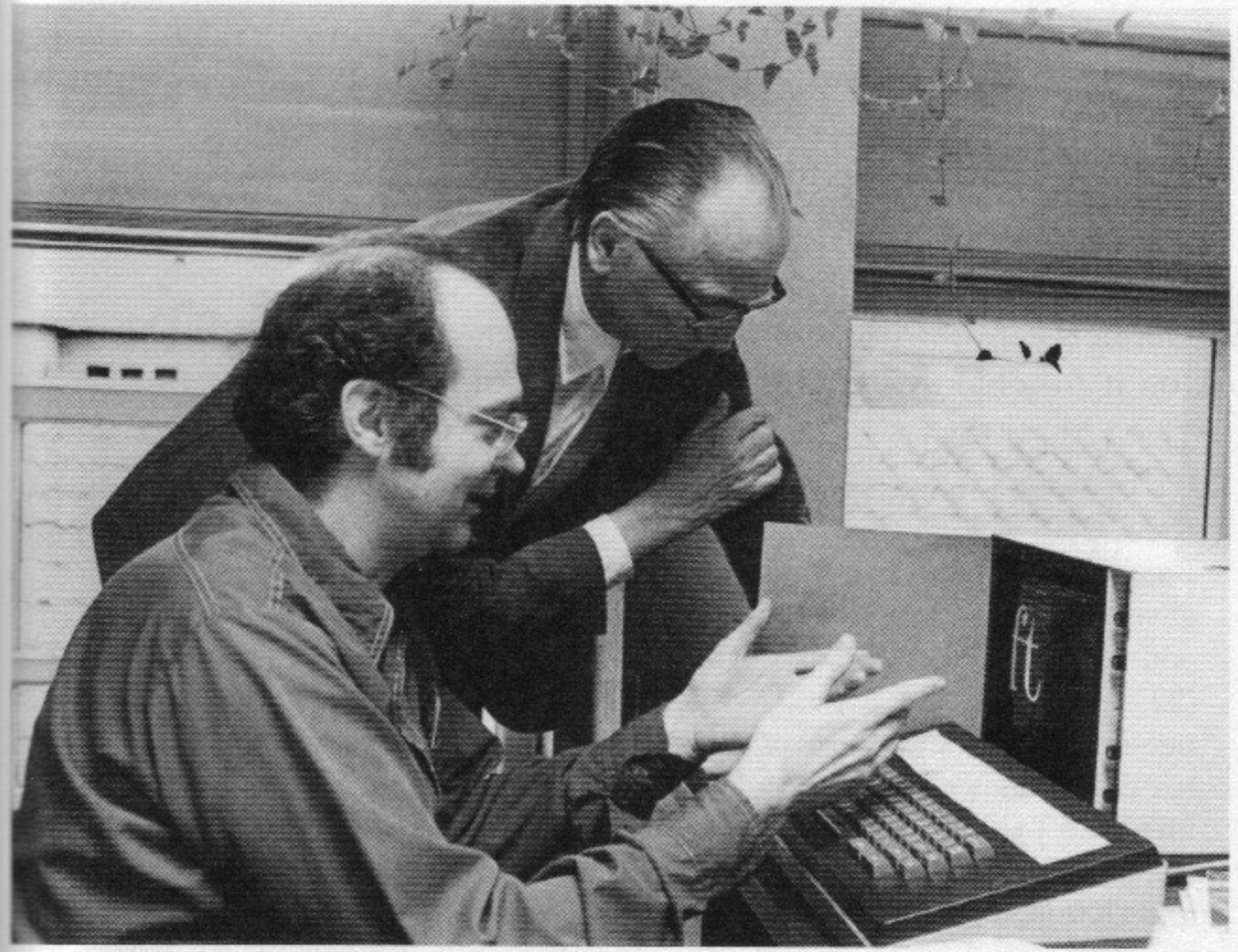
$$\left(1-\frac{1}{9}\right)\cdots\left(1-\frac{1}{n^2}\right)\left(1-\frac{1}{(n+1)^2}\right)=\frac{n+2}{2n+x}$$

The calculation holds for $n=2$ and for $n=k+4$.
Therefor it holds for $n\geq 2$. Q.E.D.

If you have that

$$\prod_{n=2}^{\infty}\left(1-\frac{1}{n^2}\right)=\frac{1}{2}$$

METAFONT



The first collaboration between DEK (seated) and HZ (standing), 14 February 1980. [Stanford News Service photo by Chuck Painter.]

FIGURE 9. Digits 0 to 9 drawn by the prototype METAFONT programs.
(Further refinements to these characters will be made before the font has its final form.)

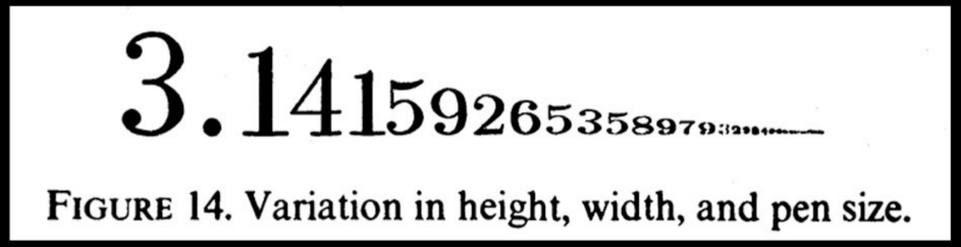


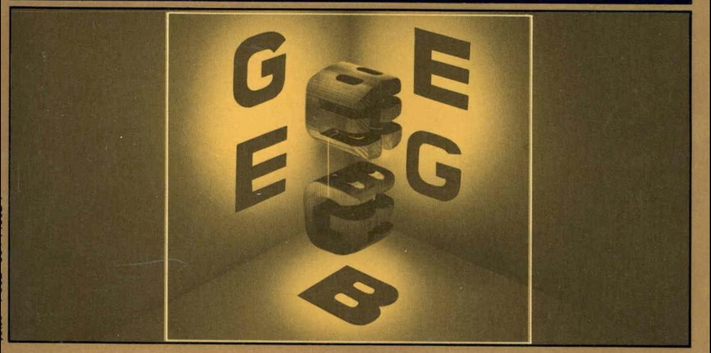
FIGURE 14. Variation in height, width, and pen size.

Computer
Modern

WINNER OF THE PULITZER PRIZE

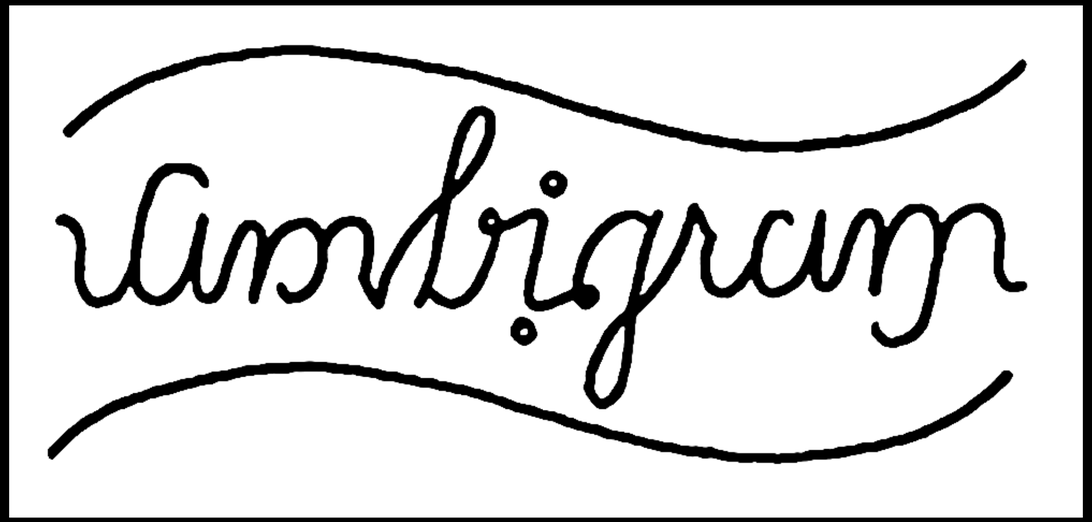
GÖDEL, ESCHER, BACH:

AN ETERNAL GOLDEN BRAID

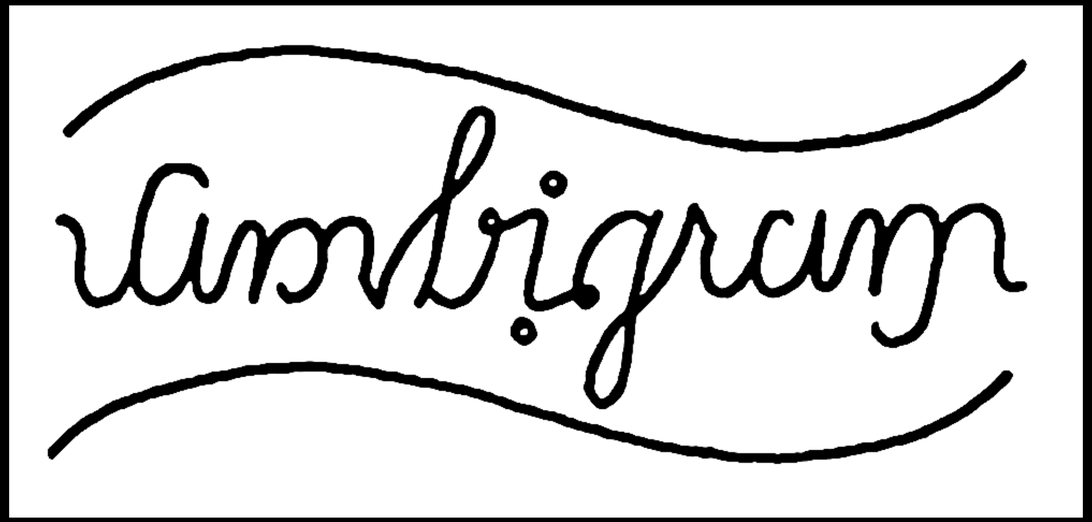


DOUGLAS R. HOFSTADTER

A METAPHORICAL FUGUE ON MINDS AND MACHINES
IN THE SPIRIT OF LEWIS CARROLL


ambigram


ambigram


ambigram


Bach

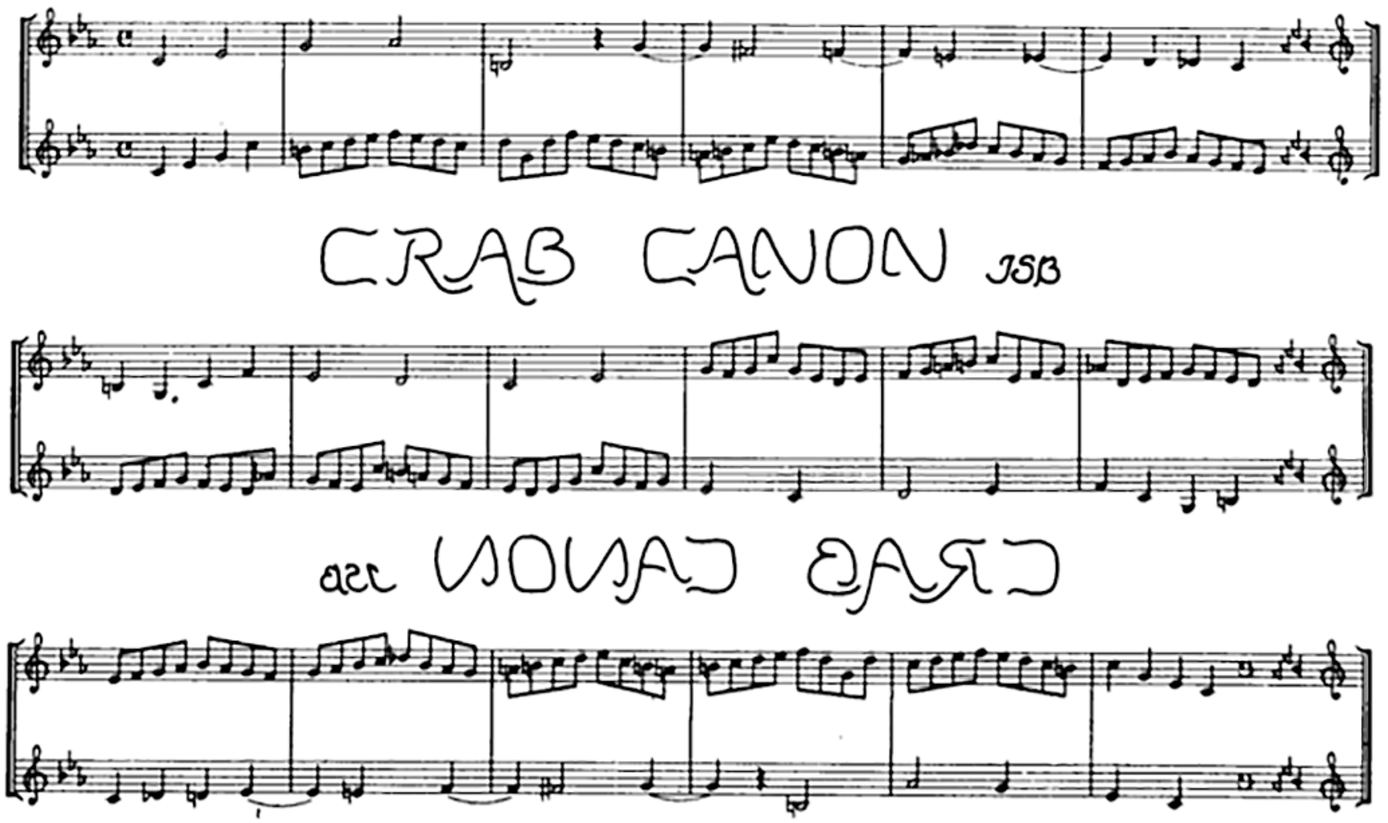
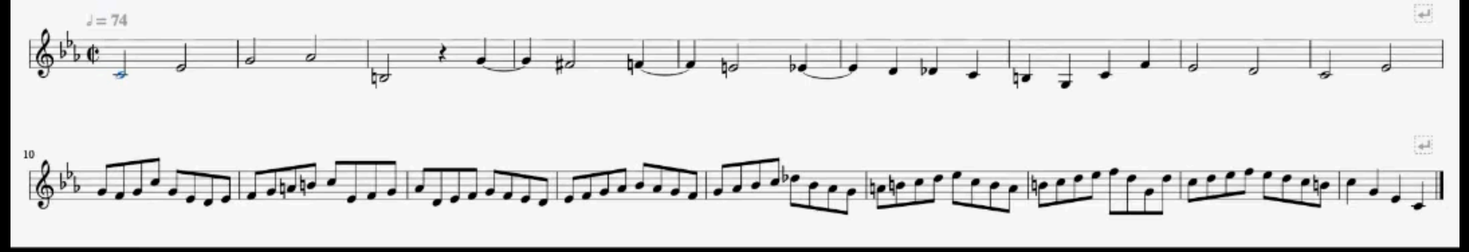
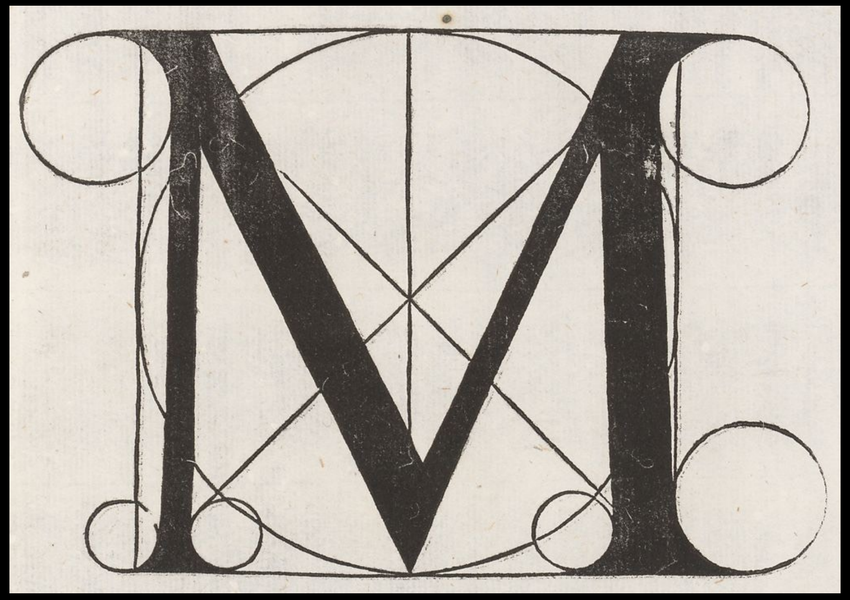


FIGURE 44. Crab Canon *from the* Musical Offering, *by J. S. Bach.* [*Music printed by Donald Byrd's program "SMUT".*]

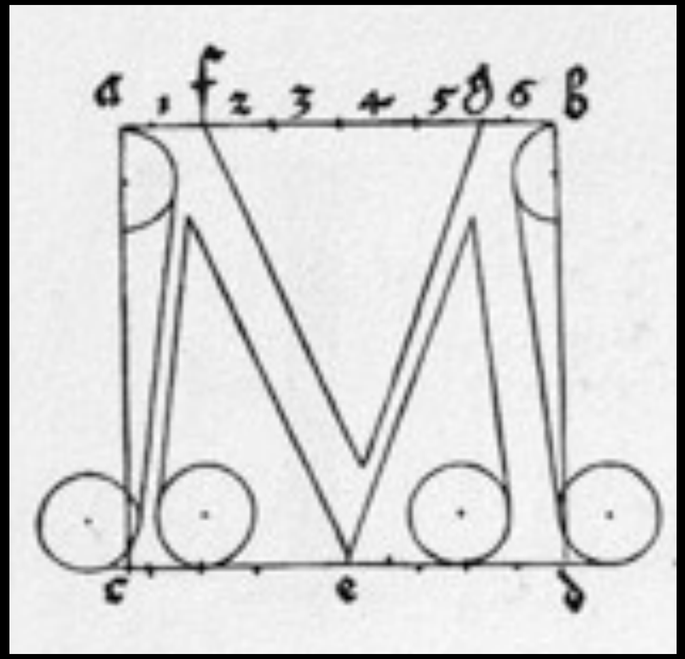

♪ = 74
10

II. RATIONALIZING THE ALPHABET

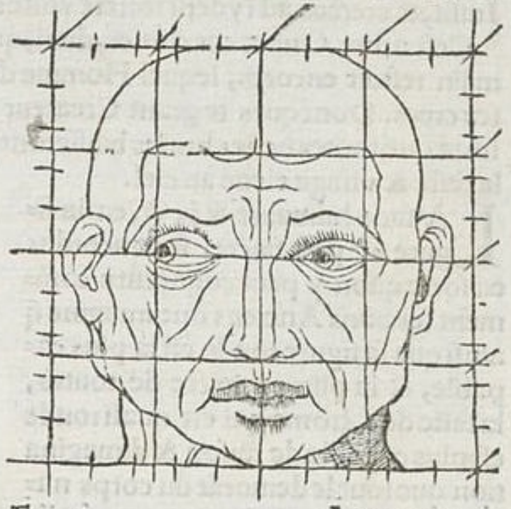

EVCLIDES
IVRIV
BVR




1500
AD
Albertus Durerus Noricus
ipsum me propria sic effin-
gebam coloribus quae-
anno aetatis XXVIII.

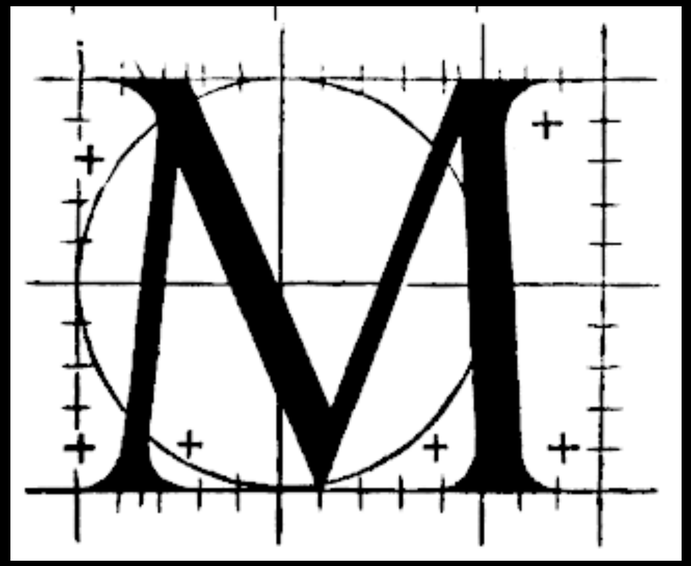

a
f
2
3
4
5
6
b
c
e
d

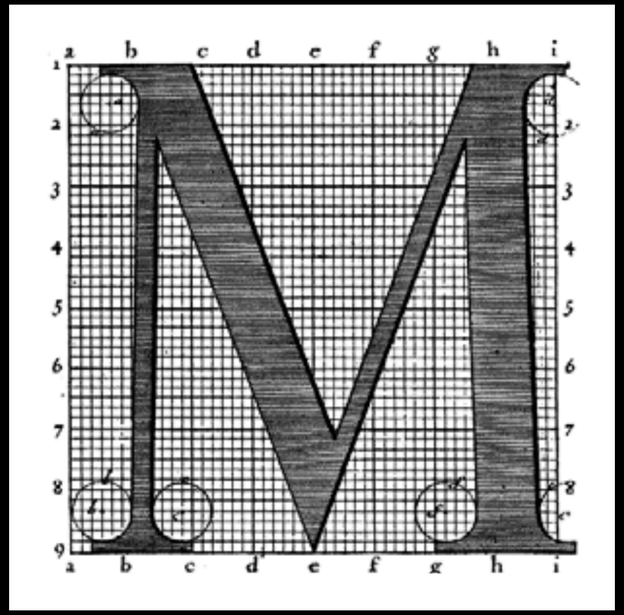
tre vertus Cardinalles pour mõſtrer q̃ noz lres Atti
certaie quadrature qui giſt en lõgitude & altitude.
eſtre entie=
tes, requie
de la haul=
eur facon,
mpas. Par
ee perſeue
& deumẽt
e, certaine
eux lignes
& a les y lo
loing lune
partiedra.
igure diui=
ommãt la
diuiſion,
runelle de
ntrique &



Significa
tion des
quatre
vertꝰ car=
dinales,
auec let=
tres Atti=
ques.

e que iay dict cy deſſus, que toute lettre ayant bri= Notable
s la dicte ligne ceutrique preciſemẽt, & nõ ailleurs. regulier.
eux yeulz, tout au lõg du nees, & deſſus la bouche
e proporti õnaire & triũphalle I. pour bailler touſ=




a b c d e f g h i
1 2 3 4 5 6 7 8 9

abcdefghijkl

mnpqrstuvw

xyzag dd

a b c d e f g h i j k l m n o p

q r s t u v w x y z

A B C D E F G H I J K L M N O

P Q R S T U V W X Y Z 1 2 3


ß123456
7890ABC
DEFGHIJKL
EMNOPQ
RSTUVW
XYZAKW

THE TIMES

No. 46,254 LATE LONDON EDITION LONDON MONDAY OCTOBER 3 1932 PRICE 2d

DEATHS (continued)

PERSONAL

PERSONAL

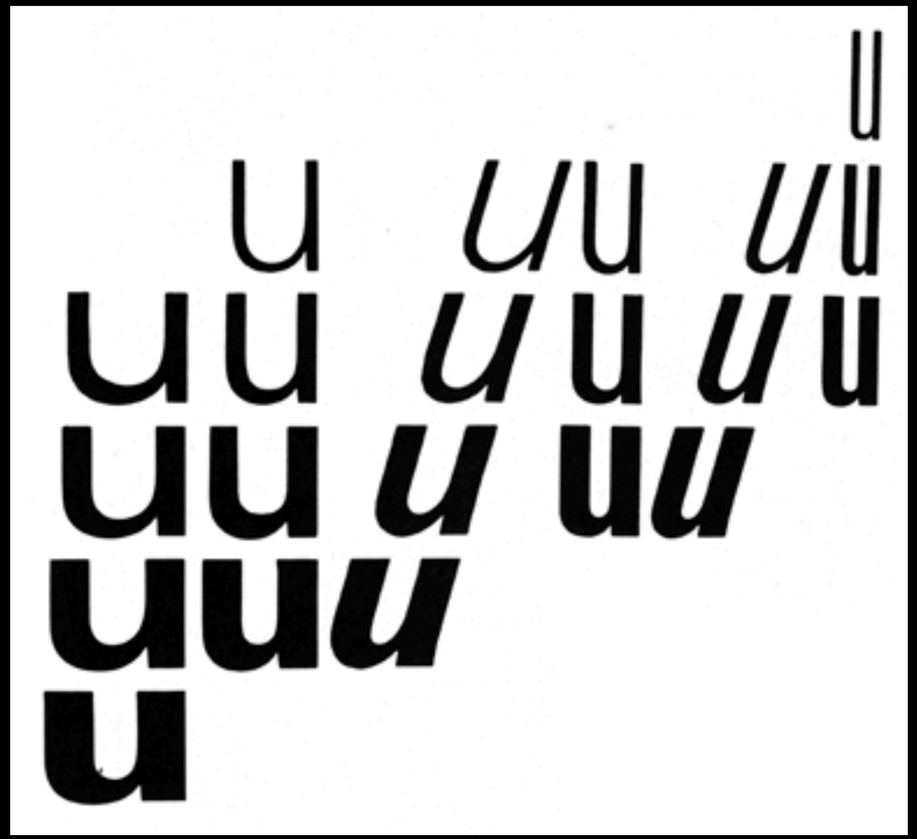
PERSONAL

BUSINESS OFFERS

CLUB ANNOUNCEMENTS

CHEPSTOW RACE CLUB.


Roman
Roman
Roman

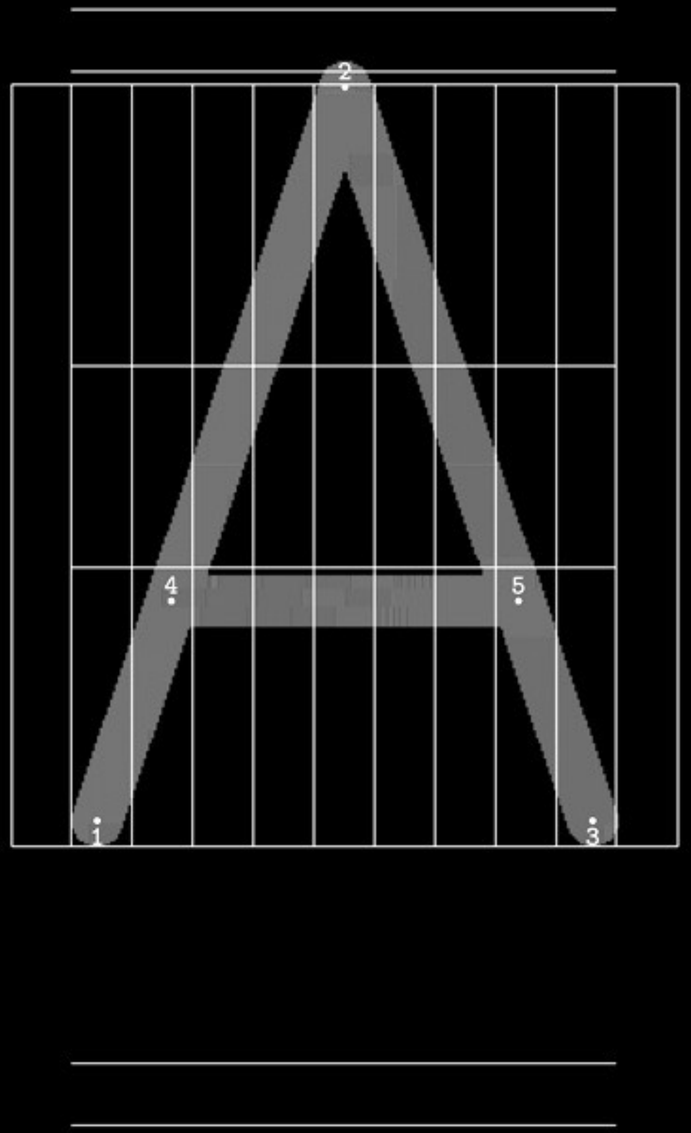


III. META-THE-DIFFERENCE-BETWEEN-THE-TWO

METAFONT

Meta-the-Difference-Between-the-2-Font

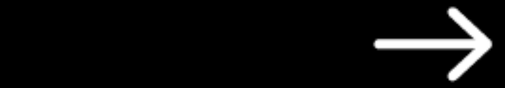
A


2
4
5
1
3

A


A

A



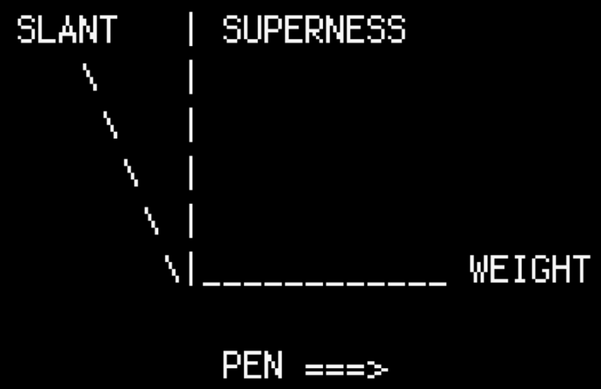
Meta-the-Difference-Between-the-2-Font

Meta-the-Difference-Between-the-2-Font

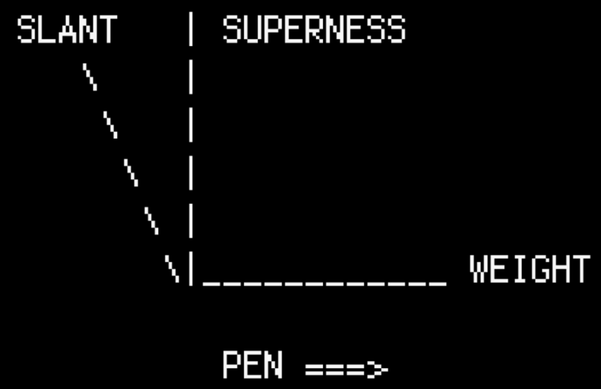
Meta-the-Difference-Between-the-2-Font

Meta-the-Difference-Between-the-2-Font

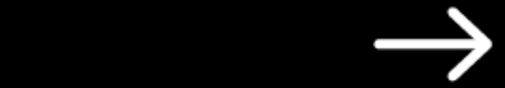
Meta-the-Difference-Between-the-2-Font


SLANT
SUPERNESS
WEIGHT
PEN ===>

```
Welcome to Meta-the-Difference-Between-the-Two-Font.
Today is Fri Mar  2 15:27:30 EST 2012
*
```

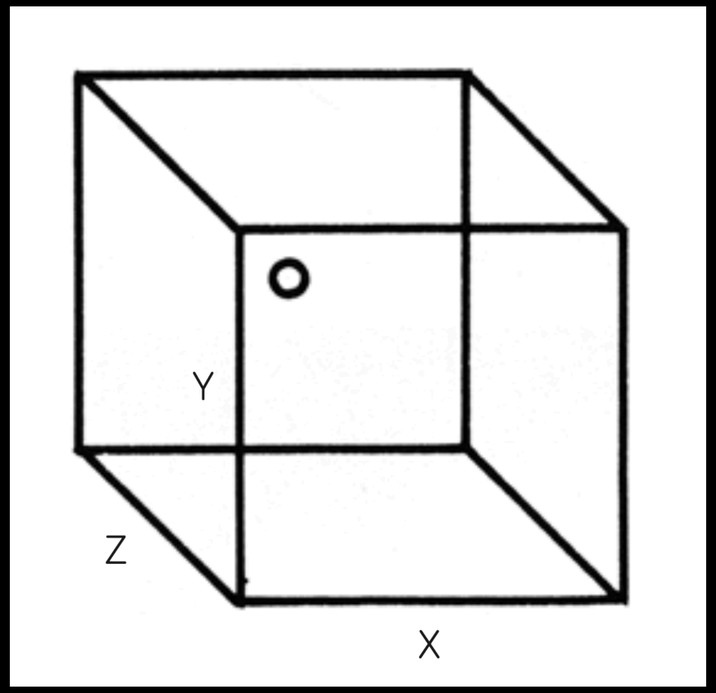



```
WEIGHT=50.000000000000000000000
SLANT=.200000000000000000000
SUPER=.575000000000000000000
PENTYPE=0
PENX=349.500000000000000000000
PENY=100
PENR=216.000000000000000000000
```



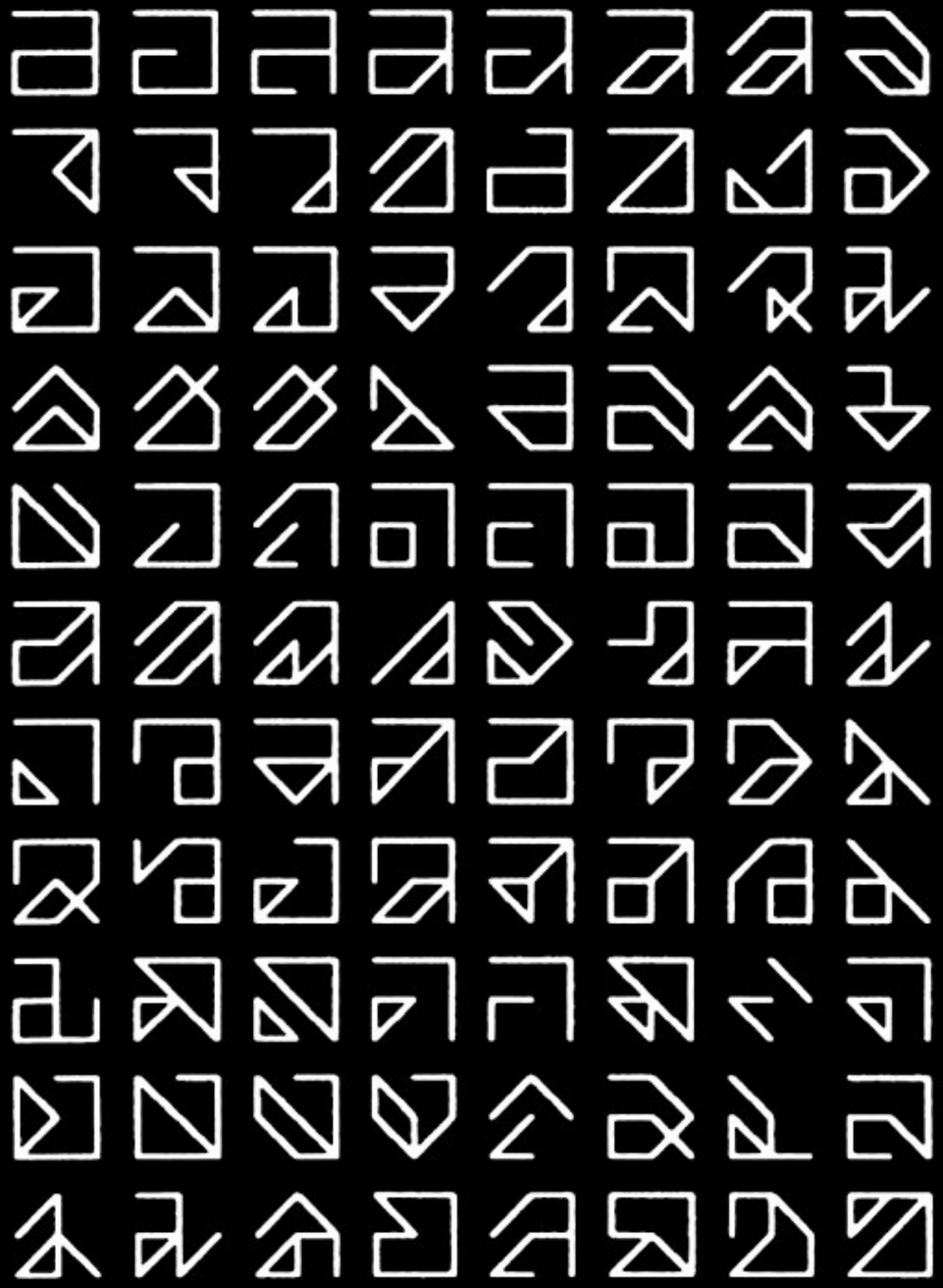
Meta-the-difference-between-the-two-Font-4-D

*


Y
Z
X

Hello world

(POSTSCRIPT)



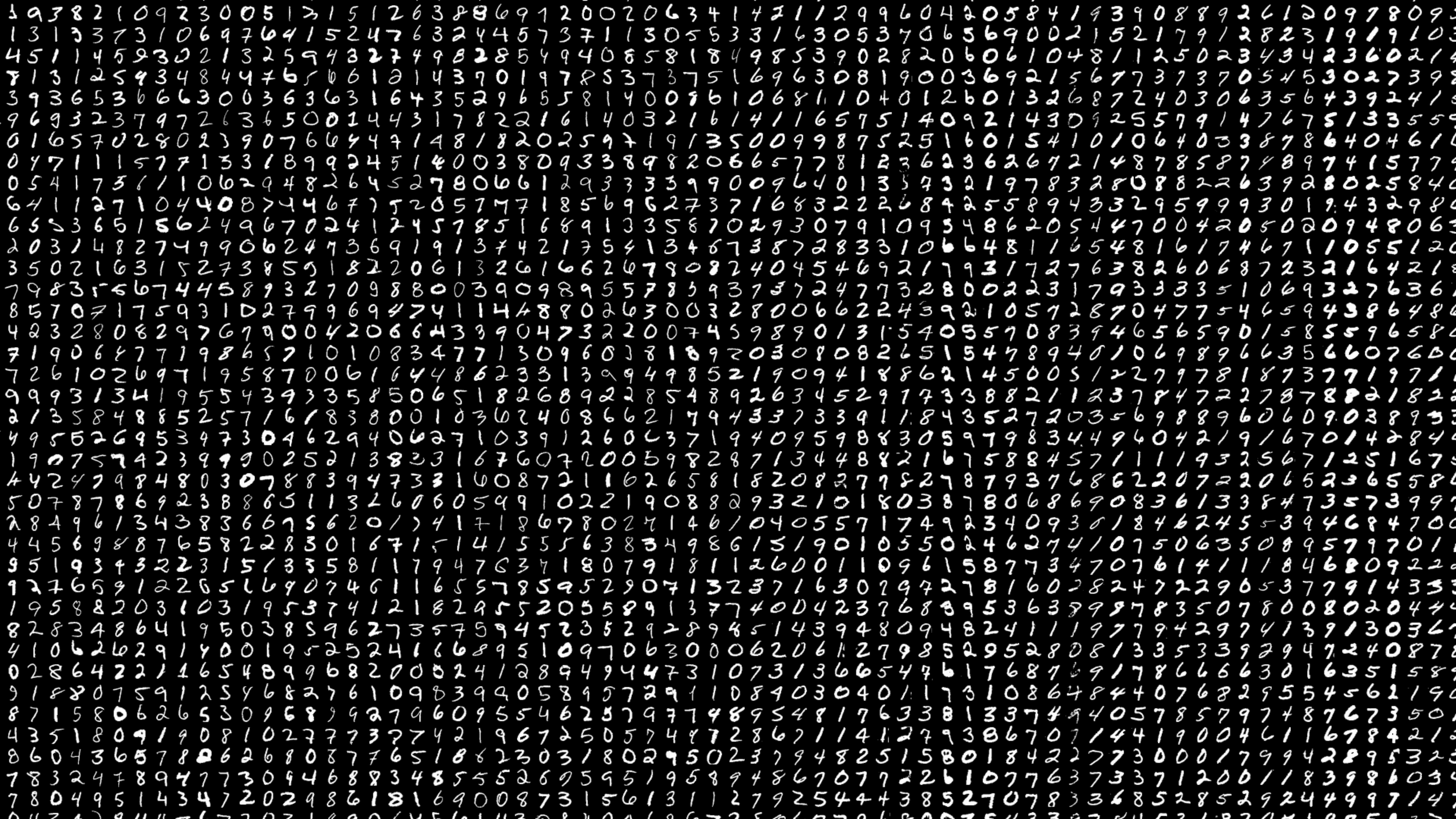
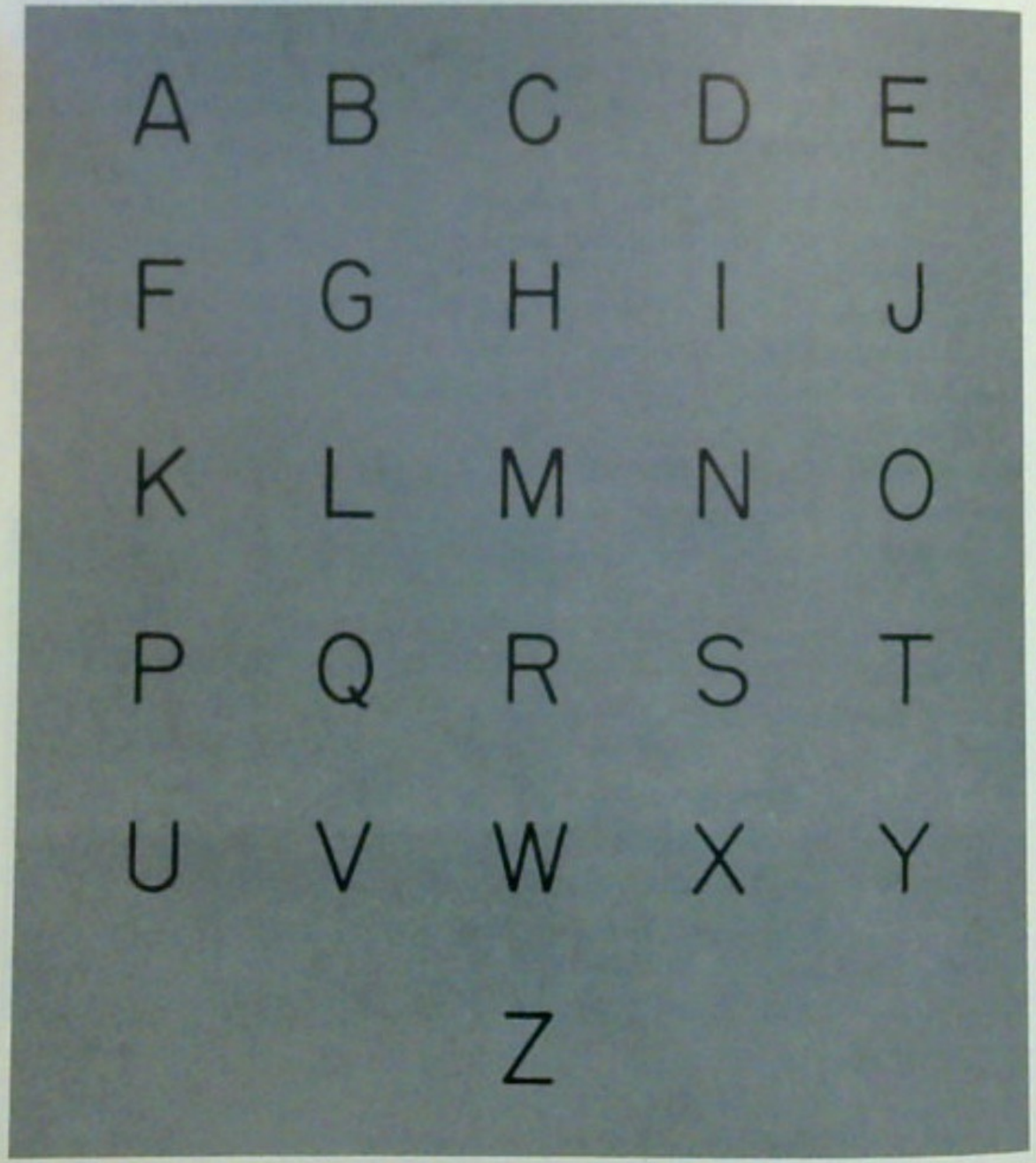


FIGURE 1.5



Every schoolboy knows that an o
sometimes he must write only on
on both sides. In this section w
which have only one side, but fi
detail exactly what surfaces we are

A surface should be "two-dime
what about a sphere with a spine
spheres (Fig. 2.1b); are these sur
special type of surface called a ma
face (i.e., a surface "all in one piec
point, the surface is topologically
for each point p of the surface, all
near to p form a set topologically
all points of the surface near to p is

Neither of the surfaces shown
the points on the spine do not ha
Fig. 2.1b the surface is not topol
point of tangency of the two sphe

A surface is *bounded* iff the en
ball. A torus is a bounded surface
we consider a particular piece of
defined to be the curve which sep
surface. For example, consider a
ary of the disk is the circle which
in a plane consists of two circles.


Gödel Ln