INVITED ARTICLE

# Digital Type Challenges

**Charles Bigelow** [a] **and Kris Holmes** [b]

[a] Cary Graphic Arts Collection, Rochester Institute of Technology, USA; [b] Bigelow & Holmes Inc.

Corresponding author: Charles Bigelow (chuck.bigelow[at]gmail.com)

**Abstract:** Second only to the invention of typography itself, digital typography has been the most transformative of the technological changes that have taken the hand setting of hand-cast and hand-printed type — the standard for 450 years — to worldwide ubiquity on the glowing screens of billions of smart phones and personal computers. Like its predecessor font technologies, digital typesetting began as a way to set text faster, but it has posed several challenges, of which the first and overarching one is resolution. Technical, perceptual, and economic in its aspects, resolution is the consequence of rendering traditionally analog forms as digital information, from pen, to punch, to photo, to pixel. Since 1980, we have designed digital type during its hegemonic advance toward world domination of literacy. That sounds scary, but the numbers seem benign: more people can now read more languages in more writing systems in more countries on more devices than ever before. The task of the type designer is to face the challenges of digital type and create the fundamental forms of what are often called fonts. We present many of the challenges we have confronted, and how we met them.

**Keywords:** design history; digital typesetting; font technology; handwriting; icons; Latin scripts; non-Latin scripts; traditional typefaces

## 1. Background

Digital typesetting began as a way to set text faster and became globally transformative, but it has posed several challenges that we, the authors, have had to confront. Before the advance of digital typesetting, we had studied calligraphy with Lloyd Reynolds, who taught not only the grace of handwriting but also the power of literacy expressed with

@: ISSUE〉 ARTICLE〉

Cite this article:

Bigelow, C., & Holmes, K. (2025). Digital type challenges. *Visible Language, 59*(1), 23–54. https://www.visible-language.org/59-1/digital-type-challenges

First published online April 27, 2025.



https://visible-language.org/journal/

**Visible Language Consortium:**
University of Leeds (UK)
University of Cincinnati (USA)
North Carolina State University (USA)

nugwagímx̣ łgá dáyaxbt, aga dánmax̣ wílxba díq̓əlpxix.
łúxwan dáwax wakáyim, łúxwan agúnax̣ alátxwida,
łá::niwa iłk̓álak̓iya łdímamt. gałə́kim, ‹‹adî::! kiníkštx̣ náyka.
nagəlgát adáłutk. idmílxam á::nga wakádaču ikdúdina.››

**Figure 1.** A passage in the Clackamas Chinook language in Syntax Antiqua. Type design by Hans Ed. Meier, diacritics by Bigelow & Holmes with Meier. Chinook narration by Victoria Howard; transcription, editing, and preparation for publication by Melville Jacobs (1958).

the simplest of tools — a skilled hand, a clear eye, a moving pen. Our first type design projects were for analog media: initial capitals for a letterpress limited-edition of *Moby Dick,* and linguistic diacritics for a phototype font of Syntax Antiqua, to compose a native American language of Oregon (Figure 1). In the *Moby Dick* capitals, we strove to express the billowing sails and flashing whale flukes of a famous American novel. With Hans Ed. Meier's Syntax, we worked to help a subtle typeface express an evocative yet nearly lost oral literature.

When we began to work with digital type, no matter how daunting its complexity and machinery, we stuck with the basics Reynolds taught: expression, simplicity, clarity. To those we added fun.

We have worked together on type design since 1976 and first encountered digital type in August 1977 on a visit to Linotype where we met Mike Parker, director of type development. There we saw large characters digitized for the new Linotron 202 digital typesetter, and we heard of the IKARUS system invented by Peter Karow for the digitization of type (Bigelow, 1979). Then in September that year, we read an article in *Scientific American* by Alan Kay (1977) with intriguing photos of the screen of the Xerox Alto personal workstation.

In 1979, our friend Michael McPherson wrote his graphic design master's thesis at Rhode Island School of Design on "Electronic Textsetting," a meticulously researched and elegantly designed forecast into the looming future of digital typography. That summer we took courses in calligraphy and type designs with Hermann Zapf at Rochester Institute of Technology (RIT). We learned of Zapf's own digital typefaces, Marconi and Edison, and heard his persuasive argument that type design for new technologies should be new and original.

In 1981, Patricia Seybold and John W. Seybold of the Seybold Consulting Group encouraged us to write up our studies of digital type for the typesetting industry journal, the

*Seybold Report* (Bigelow & Seybold, 1981; Bigelow & Seybold, 1982a,b). In 1982, Bigelow (the first author) was appointed assistant professor of digital typography at Stanford, and with Donald Day wrote about digital typography for *Scientific American* magazine (Bigelow & Day, 1983).

That same year, Bigelow organized a seminar, "The Computer and the Hand in Type Design," at Stanford for the Association Typographique Internationale (ATypI). The August seminar featured working demonstrations of new computer tools for creating digital type, along with live demonstrations of traditional letter arts including carving in stone, punch cutting in steel, and casting in lead, with a calligraphic keepsake of quotes from women storytellers in history. The seminar featured lectures by type designer Hermann Zapf, typographer and scholar John Dreyfus, printer Jack Stauffacher, computer scientist Donald Knuth, stone carver John Benson, and other type designers and lettering artists.*

The Stanford seminar revealed more challenges of digital type.

## 2. Twelve Challenges

### 2.1. Challenge 1: Resolution and Pixels

Unlike the smooth analog forms of traditional metal and photographic printing types, digital type is composed of small picture elements, or *pixels.* The term *resolution* is often used to mean *pixel density,* the number of pixels per unit of measure (e.g., inch [ppi] or centimeter).†

Without digital equipment, we first experimented with letter type designs for computer screens using graph paper, filling in squares to simulate bitmaps of letters. At that time, cathode-ray tube screen resolutions were around 72 pixels per inch, at which a 12-point font was conveniently 12 pixels tall and its stems one pixel thick. A simulated italic font would have one or two jags in its stems, depending on italic angle, and a bold weight would have stems two pixels thick. No in-between weights were possible. A few years after our early experiments, we designed working screen fonts for personal workstations, particularly the DEC VaxStation 1 and the Tektronix Smalltalk workstation (Bigelow, 1986).

---

* The seminar was documented through proceedings in a 1985 *Visible Language* special issue, "The Computer and the Hand in Type Design," with guest editors Charles Bigelow and Lynn Ruggles (Bigelow, 1985).

† Alvy Ray Smith (2021), a co-founder of Pixar, provides a comprehensive account of the pixel in theory and practice, and Robert Morris (1989) provides a discussion of the perception of type quality at digital resolutions.

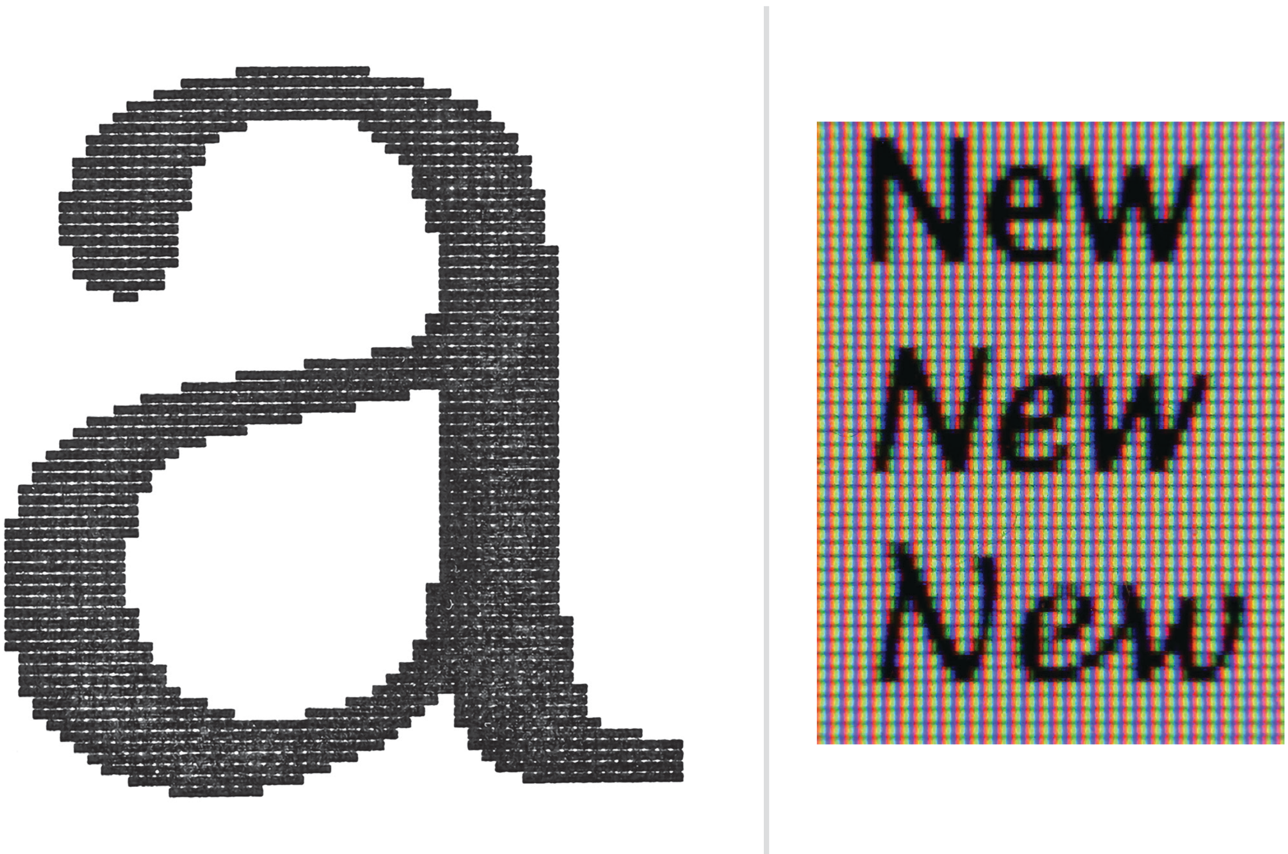



**Figure 2.** Enlarged bitmap of the letter "a" from Edison, showing typical "staircasing" of pixels on curves, limited by resolution (left). This resolution is high enough that the staircases are softened at small sizes on newsprint. For a reproduction of digital display: a close capture of Lucida variations — roman, italic, handwriting — at a screen resolution around 90 pixels per inch (right).

**Marconi and Edison.** We were hardly the first to design fonts by bitmap construction. In 1976, Hermann Zapf, assisted by his wife Gudrun Zapf von Hesse, created high resolution bitmap typefaces for the Digiset typesetting machines of Doktor-Ingenieur Rudolf Hell (Zapf, 2000). First they designed the Marconi family for headlines of newspapers, the major users of Digiset equipment. The Zapfs created the digital letters pixel by pixel, using pre-ruled grids. In 1978, their next digital font family was Edison, a newspaper text face likewise for the Digiset. At high resolution, around 230 pixels per centimeter, Digiset pixels blended together to produce smooth letters like standard news faces (Figure 2). Later, both families were produced by Dr.-Ing. Hell as digital outline fonts, using the IKARUS system, invented by Peter Karow in Hamburg, Germany (Karow, 1998, 2019). It is difficult at this far remove in time to convey how exciting it was for us to learn that two of the most esteemed type designers of the 20th century were creating digital fonts.

## 2.2. Challenge 2: Type Revivals as Digital Fonts

In the 1970s, a few methods of defining letter outlines by computer were invented. The most efficient use of IKARUS began with large outline letter drawings, which reduced the amount of subsequent editing needed compared to digitizing photographic enlargements of letters.

In the early 1980s, Dr.-Ing. Hell engaged Holmes (the second author) to draw versions of classical 18th century typefaces Baskerville and Caslon for IKARUS digitization and adaptation to Hell's digital typesetting equipment (Figure 3). Although digitizing 20th century phototype versions of classical faces had become common, Holmes instead studied specimens of original Baskerville punches and type cast from their matrices by the Parisian Deberny & Peignot foundry in Paris, as well as microscopic examination of 19th century Baskerville specimens from the Frères Bertrand type foundry. Based on these, Holmes drew large, precise outlines on dimensionally stable drafting mylar, in order to avoid paper shrinking or expansion when sending drawings from the U.S. to Kiel, Germany, where Dr.-Ing Hell was located. Dr.-Ing. Hell had asked that Holmes' drawings regularize features such as stems, serifs, and alignments, to conform to Hell's Digiset machine resolutions.

## 2.3. Challenge 3: Original Design from Outlines for Digital Systems

**Isadora.** In the early 1980s, Dr.-Ing. Hell planned to introduce smaller versions of Digiset machines in the American market for smaller newspapers and publications as well as commercial and advertising typography. The firm wanted a new typeface that would show off the creative possibilities of its digital machines.

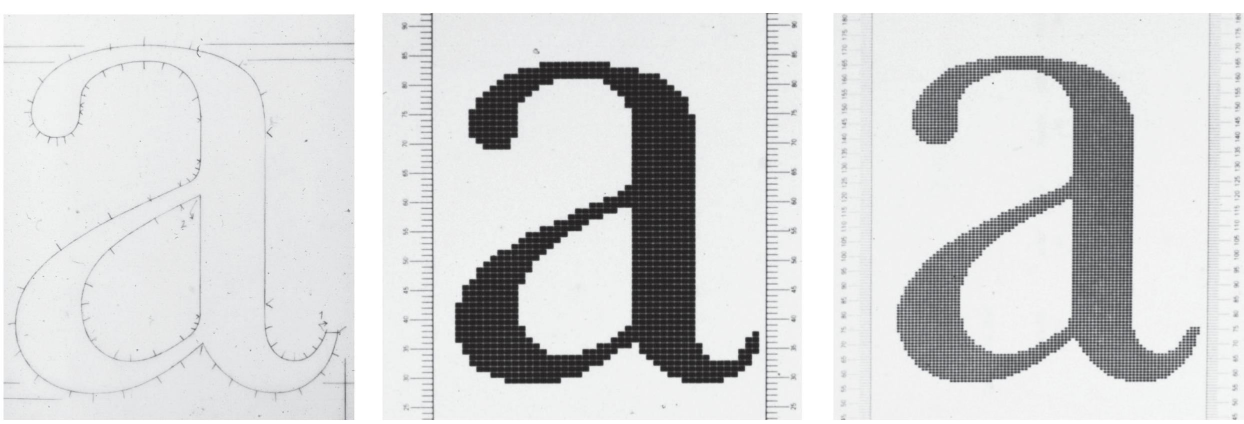


**Figure 3.** Drawing of Baskerville lowercase letter "a" by Kris Holmes, circa 1980, adjusted to Digiset grid, with IKARUS spline indicators (the little tick marks).

In traditional metal typography, the connecting script typeface was among the most difficult styles to cast and print well. Delicate hairlines and serifs tended to break, exposing gaps instead of connections. Highly slanted scripts were also difficult to achieve in metal. Holmes felt that those problems could be solved in digital typesetting, so she proposed to Hell a new script face to show off the Digiset machine's ability to render elegant designs in fashion and display advertising (Figure 4). Her name for it was Isadora, evoking the grace and originality of the famed early modern dancer, Isadora Duncan. Holmes' design proposal met with approval from advisers to Dr.-Ing. Hell, Hermann Zapf and Swiss designer Max Caflisch (Holmes, 1985, 2015). Holmes designed her flourished script while implementing the careful adjustments and regularities needed for the resolutions of Hell's typesetters. Her large, fine-line drawings were digitized with the IKARUS program. Some years later, the International Typeface Corporation (ITC) acquired Isadora for general licensing to phototype equipment manufacturers as well as digital manufacturers.

## 2.4. Challenge 4: Laser Printing and Hi-Res Typesetting

After the seminar "The Computer and the Hand in Type Design," we began work on a new type family for laser printing and screen display. We named the type Lucida to signify that it would be rendered with light — laser light in print and phosphorescent light on cathode-ray tubes. We believed that with simple and regularly repeated letter shapes, the type could be rendered reasonably well by laser printers, despite distortion and noise in the medium resolution printers. We crafted basic patterns for serifs, stems, bowls, and other features, and repeated those throughout the typeface. The result was a sturdy design intended to be a workhorse at text sizes at medium resolution (Figure 5).

In 1984, Michael Sheridan, director of typography at Imagen, a laser printer manufacturer in Silicon Valley, welcomed the challenge of producing Lucida for 300 dpi Imagen laser printers. To generate digital outline data for the printer company, we drew large outlines of Lucida letters and digitized them with IKARUS. Imagen converted our IKARUS data to their proprietary printer font format and produced the first specimen of Lucida as a keepsake for the September 1984 meeting of ATypI in London, England (Bigelow & Holmes, 1986, 2018).

Serifed Lucida was found to be resistant to digital noise and maintained adequate readability in 300 dpi printing (Bowden & Brailsford, 1989), and Adobe found that it also remained more legible after faxing than some other typefaces. Progress in rasterization technology soon made it possible to render refined type designs at medium resolutions, so the original serifed Lucida was not as necessary, but it served as the basis for an extended family of future design variations.

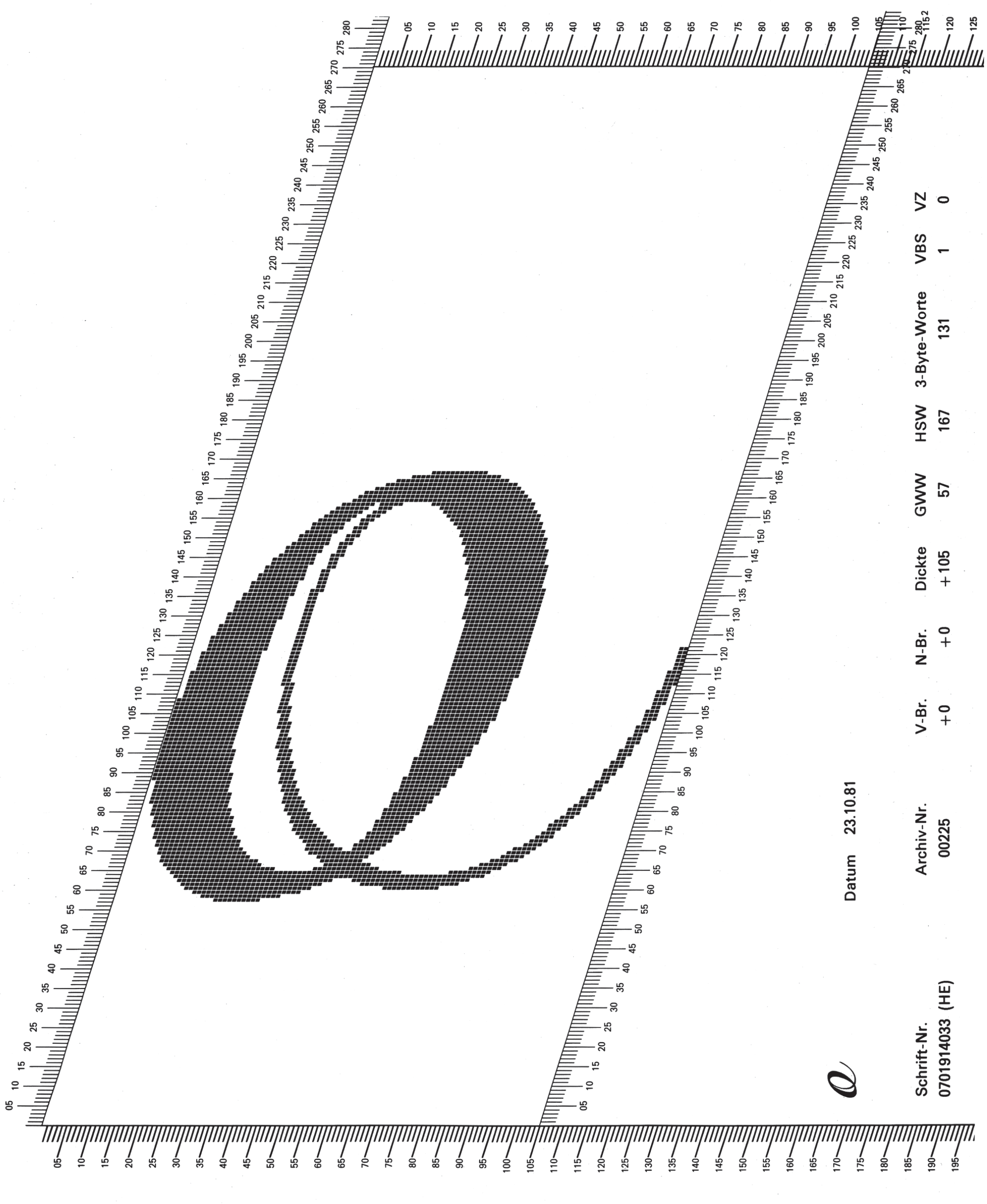
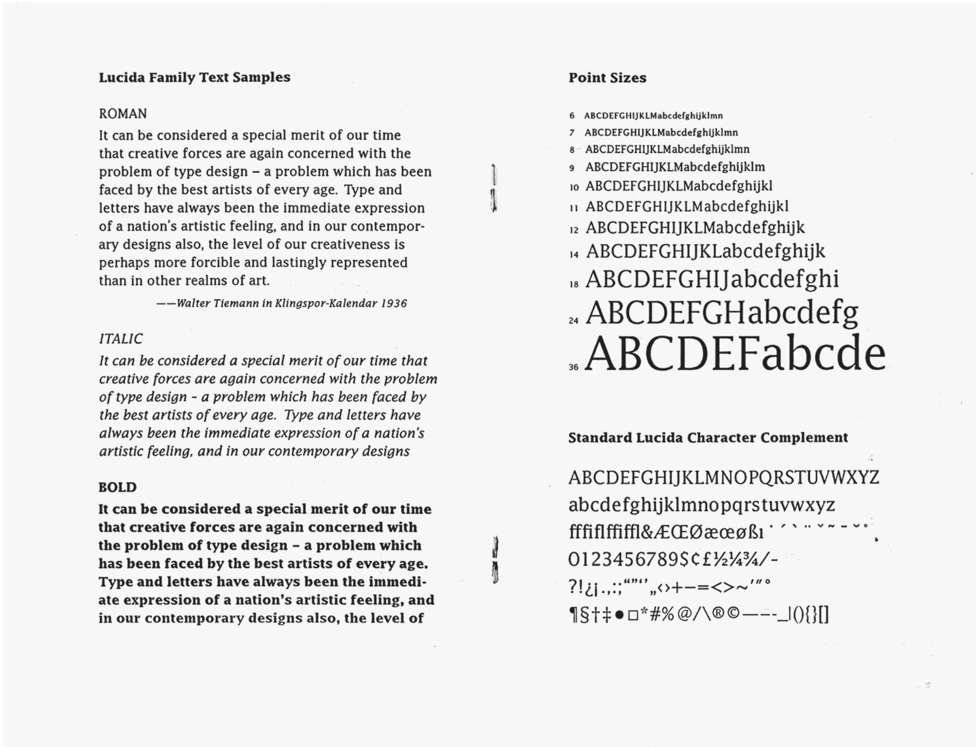



**Figure 4.** Isadora “o” clean proof for Digiset.


**Lucida Family Text Samples**

ROMAN
It can be considered a special merit of our time that creative forces are again concerned with the problem of type design – a problem which has been faced by the best artists of every age. Type and letters have always been the immediate expression of a nation's artistic feeling, and in our contemporary designs also, the level of our creativeness is perhaps more forcible and lastingly represented than in other realms of art.
*——Walter Tiemann in Klingspor-Kalendar 1936*

*ITALIC*
*It can be considered a special merit of our time that creative forces are again concerned with the problem of type design – a problem which has been faced by the best artists of every age. Type and letters have always been the immediate expression of a nation's artistic feeling, and in our contemporary designs*

**BOLD**
**It can be considered a special merit of our time that creative forces are again concerned with the problem of type design – a problem which has been faced by the best artists of every age. Type and letters have always been the immediate expression of a nation's artistic feeling, and in our contemporary designs also, the level of**

**Point Sizes**

6 ABCDEFGHIJKLMabcdefghijklmn
7 ABCDEFGHIJKLMabcdefghijklmn
8 ABCDEFGHIJKLMabcdefghijklmn
9 ABCDEFGHIJKLMabcdefghijklm
10 ABCDEFGHIJKLMabcdefghijkl
11 ABCDEFGHIJKLMabcdefghijkl
12 ABCDEFGHIJKLMabcdefghijk
14 ABCDEFGHIJKLabcdefghijk
18 ABCDEFGHIJabcdefghi
24 ABCDEFGHabcdefg
36 ABCDEFabcde

**Standard Lucida Character Complement**

ABCDEFGHIJKLMNOPQRSTUVWXYZ
abcdefghijklmnopqrstuvwxyz
fffiflffiffl&ÆŒØæœøßı ˙ ´ ` ¨ ˇ ˜ ¯ ˘ ˚ ¸
0123456789$¢£½¼¾/-
?!¿¡.,:;“”‘’„‹›+−=<>~′″°
¶§†‡●□*#%@/\®©—–-_|(){}[]

**Figure 5 (above).** Imagen Lucida specimen, laser printed at 300 dots per inch in 1984.

| Lucida Sans Weights | CSS |
| --- | --- |
| a quick brown fox | 100 |
| a quick brown fox | 150 |
| a quick brown fox | 200 |
| a quick brown fox | 250 |
| a quick brown fox | 300 |
| a quick brown fox | 350 |
| a quick brown fox | 375 |
| a quick brown fox | 400 |
| a quick brown fox | 425 |
| a quick brown fox | 450 |
| a quick brown fox | 500 |
| a quick brown fox | 550 |
| a quick brown fox | 600 |
| a quick brown fox | 650 |
| a quick brown fox | 700 |
| a quick brown fox | 800 |
| a quick brown fox | 900 |
| a quick brown fox | 999 |

**Figure 6 (left).** The gamut of 18 Lucida Sans weights. A humanist sans-serif in barely noticeable weight differences for graphic and interface designers to fine-tune perceptual and psychological nuances for different contexts and functions. The numbers represent weight designations in Cascading Style Sheets (CSS) for online typography.

SCIENTIFIC AMERICAN October 1987 Volume 257 Number 4

The Next Computer Revolution

*In less than 50 years computers have become essential to industrial society; in the next phase they will grow more powerful by at least an order of magnitude and become a ubiquitous intellectual utility*

by Abraham Peled

When it was first invented, the computer was an interesting laboratory curiosity. Today it is inconceivable that contemporary industrial society could exist without it. The domestic and international financial industry, manufacturing and transportation all rely on electronic flows of information. Technologists who design materials or biologically derived pharmaceuticals depend on the computer, as do physicists who are exploring the nature of energy and matter. The way network will be capable of linking any combination of individuals who need computing, whether they are physicians trying to reach a difficult diagnosis, investment bankers structuring a deal, aeronautical engineers creating a new airframe, astrophysicists modeling the evolution of the universe or students studying for an examination.

Although the emergence of such an intellectual utility represents a profound change in society's relation

cult yet feasible engineering refinement of current technologies [see "Chips for Advanced Computing," by James D. Meindl, page 78]. X-ray lithography using synchrotron radiation, new materials and better device structures will probably improve the density of components on a chip by a factor of 20 to 40. Such processors will probably be from six to 12 times faster than existing ones.

These improvements will be compounded by the steady increase of parallelism in computing systems.

**Figure 7.** Lucida Bright was a new version of Lucida for high-resolution digital typesetting around 720 dots per inch, more than twice laser printer resolution at the time. The titles of the article are Galileo roman and the subtitles are Galileo italic.

**Lucida Sans.** In 1985, we finished a family of sans-serif companion faces for Lucida (Figure 6). The concept of uniting serif and sans-serif faces in a single family was not original to us. It was first conceived by Dutch type designer and calligrapher Jan van Krimpen in the 1930s at the Enschedé printing house and type foundry. We had first gotten the idea in the early 1970s from an essay by Erich Schulz-Anker (1970) comparing the humanist sans-serif typeface Syntax-Antiqua, by Hans Eduard Meier, to the humanist serifed Sabon typeface, by Jan Tschichold. Lucida Sans has since proven popular, having been licensed and distributed by Adobe, Apple, Bell Labs, Microsoft, Monotype, Sun Microsystems, Oracle, the TeX Users Group, and other firms and organizations.

**Lucida Bright.** In 1986–1987, when we redesigned *Scientific American* magazine for more expressive use of digital typography, we created Lucida Bright for the text. With refined modulation, thinner hairlines, longer serifs, and tighter letter-fitting to narrow columns, Lucida Bright gave a brighter look on the coated paper of the magazine (Figure 7). We used Lucida Sans for other contexts in the magazine, thus carrying out our concept that serif and sans-serif of the same extended family can be used together effectively.

**Galileo.** We designed an even brighter typeface for article titles in *Scientific American.* It had very high-contrast between strong vertical stems and very thin hairlines and serifs in the Didot style that had been used in the magazine before the digital era (Figure 7). Thus, there were three levels of "brightness" in the magazine, depending on the degree of contrast between thick and thin letter elements: high contrast in the titling; medium contrast in the Lucida Bright running text; and low contrast in the Lucida Sans sections. We called the face Galileo but did not release it to the general market. Perhaps someday we will.

**Lucida Fax.** In 1992, Microsoft included Lucida Bright and Lucida Sans in the Microsoft Font Pack for Windows, along with Lucida Fax, a version of the original Lucida serifed face modified for faxing.

**Lucida RSVP.** Around the year 2001, Robert Morris, a mathematician and computer scientist with strong interests in imaging and typography, asked us to assist in a laboratory experiment investigating a perennial debate in 20th century typography: Which type style is more legible, serifed or sans-serif? Previous studies of the question were less than persuasive because the sample faces were usually disparate in most salient features. For example, in a study comparing serifed Times Roman with the sans-serif Helvetica, the two typefaces differed in x-height, capital height, ascender and descender lengths, character widths, inter-letter spacing, stem thickness, hairline thickness, underlying letterforms, and overall weight (the ratio of black to white).


**Figure 8.** Lucida RSVP, with color indicating the removal of serifs from a Lucida Fax base for an experimental study testing the legibility of serifed versus sans-serif type.

For Morris' study, we took Lucida Fax and removed the serifs from one version and left them on another (Morris et al., 2002). We made a few other adjustments in lockstep between the faces, so that ultimately they differed in only one respect, the presence or absence of serifs (Figure 8). The experiment was conducted with a computerized text presentation technique called *rapid serial visual presentation,* or RSVP, in which the words of a text are rapidly flashed on the center of a computer screen as readers passively focus on the screen without significantly moving their eyes. Hence, we called the new font Lucida RSVP. The study concluded that during RSVP, reading for sans-serif type is approximately 20% faster at very small sizes. But at larger sizes, this advantage disappeared. Thus, it may be "counterproductive" to render serifs at small sizes.

## 2.5. Challenge 5: Monospaced

*Typewriter, fixed-pitch, fixed-width,* and *monospaced* are equivalent terms for typefaces in which all letters and characters have the same set width (Figure 9). That is, the horizontal width of each letter, including not only the black letter but also the white areas on its sides, are identical. The space occupied by an "i" is the same width as the space of an "m." This was the standard form of most typewriter fonts for more than a hundred years because it enabled simpler mechanisms and easier typing. Early computer systems and applications, particularly for programming and line printing, often assumed monospaced fonts, including those that had been designed for IBM typewriters, including the famous Courier by Howard Kettler and Letter Gothic by Roger Roberson.

**Lucida Sans Typewriter.** In 1986, Imagen asked us to make a monospaced version of Lucida Sans for programmers who used systems and applications that assumed fixed-pitch fonts. Accordingly, we "monospace-ized" Lucida Sans, giving the letters and characters equal widths while keeping the x-height and vertical proportions identical to those of Lucida Sans. The result looked a lot like Lucida Sans — a quick glance might not reveal a difference between the proportionally spaced and monospaced versions. In the dawn of personal computing in 1986, millions of people still used typewriters, so we called the monospaced design Lucida Sans Typewriter. More robust in weight but more economical in space than Courier, it became popular among Imagen's customers.

We added bold, italic, and bold italic styles to make a typeface family, which Microsoft included in its Font Pack for Windows in 1992. In 2018, after most people had stopped using mechanical typewriters, we added Greek and Cyrillic alphabets along with symbol and graphics characters to Lucida Sans Typewriter and renamed it Lucida Grande Mono. (Well, the "Grande" is because it is more grandiose than its first incarnation.)

**Lucida Console.** Next, Microsoft asked us to modify Lucida Sans Typewriter for the "console" window in its operating systems. To fit the font into display limitations of that

ABCDEFGHIJKLMNOPQRSTUVWXYZ
abcdefghijklmnopqrstuvwxyz
abcdefghijklmnopqrstuvwxyz
*ABCDEFGHIJKLMNOPQRSTUVWXYZ*
*abcdefghijklmnopqrstuvwxyz*
**ABCDEFGHIJKLMNOPQRSTUVWXYZ**
**abcdefghijklmnopqrstuvwxyz**
**abcdefghijklmnopqrstuvwxyz**
***ABCDEFGHIJKLMNOPQRSTUVWXYZ***
***abcdefghijklmnopqrstuvwxyz***
ABCDEFGHIJKLMNOPQRSTUVWXYZ
abcdefghijklmnopqrstuvwxyz
*ABCDEFGHIJKLMNOPQRSTUVWXYZ*
*abcdefghijklmnopqrstuvwxyz*
**ABCDEFGHIJKLMNOPQRSTUVWXYZ**
**abcdefghijklmnopqrstuvwxyz**
***ABCDEFGHIJKLMNOPQRSTUVWXYZ***
***abcdefghijklmnopqrstuvwxyz***
ABCDEFGHIJKLMNOPQRSTUVWXYZ
abcdefghijklmnopqrstuvwxyz
*ABCDEFGHIJKLMNOPQRSTUVWXYZ*
*abcdefghijklmnopqrstuvwxyz*
**ABCDEFGHIJKLMNOPQRSTUVWXYZ**
**abcdefghijklmnopqrstuvwxyz**
***ABCDEFGHIJKLMNOPQRSTUVWXYZ***
***abcdefghijklmnopqrstuvwxyz***

ABCDEFGHIJKLMNOPQRSTUVWXYZ
abcdefghijklmnopqrstuvwxyz
*ABCDEFGHIJKLMNOPQRSTUVWXYZ*
*abcdefghijklmnopqrstuvwxyz*
**ABCDEFGHIJKLMNOPQRSTUVWXYZ**
**abcdefghijklmnopqrstuvwxyz**
***ABCDEFGHIJKLMNOPQRSTUVWXYZ***
***abcdefghijklmnopqrstuvwxyz***

**Figure 9.** Digital typewriter variations showing different styles, weights, widths, postures, and details of monospaced versions of Lucida.

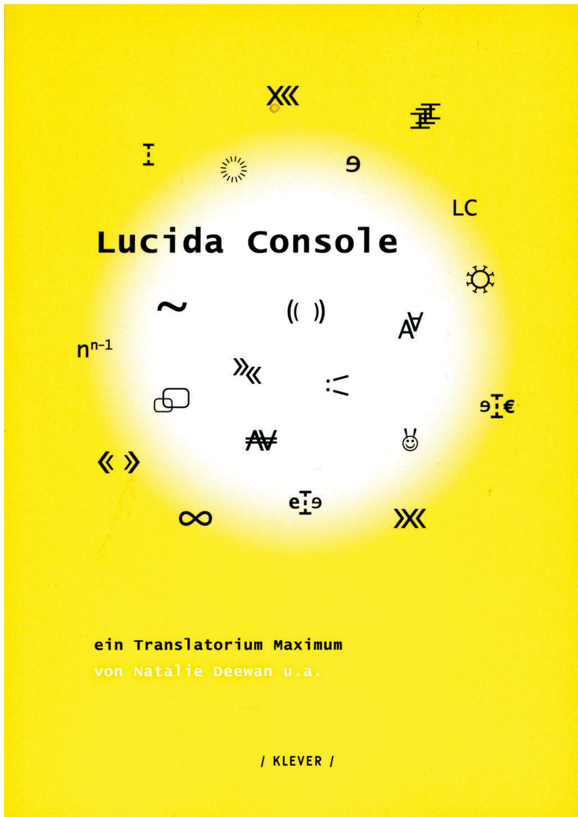



**Figure 10.** *Lucida Console,* book by avant-garde writer Natalie Deewan (2022).

special window, we shortened the capitals so European accents could fit into limited space, and to expand the international utility of the face, we added Greek and Cyrillic letters and accents, along with sets of symbols and graphic characters, almost tripling the number of characters in a standard font.

This niche adaptation to a particular operating system turned out to look unexpectedly cute and attracted an avant-garde following. An English rock band called itself The Lucida Console, and an avant-garde writer in Vienna wrote a multilingual, McLuhanesque book entitled *Lucida Console* using the eponymous font (Figure 10; Deewan, 2022). One of the thrills of designing typefaces is seeing them used in adventurous, imaginative, and unexpected ways.

**Lucida Typewriter.** After Lucida Sans Typewriter, we were asked for a serifed monospaced font. The most successful typewriter face of all time is Courier, which was designed by Howard Kettler for IBM electric typewriters in the 1950s. Courier is a subtle but superb design, and though often imitated, IBM's original design remains superior to the later but cruder imitations.

Instead of attempting to imitate Courier, we adapted Lucida Fax to monospacing, relying on its proven resistance to digital noise and its more robust weight to serve as a sturdy workhorse when a monospaced face is needed. At 10 point, Lucida Typewriter fits 10 characters per inch, the same as 12 point Courier, thus being more economical in its vertical dimension than Courier, with a more chiseled appearance.

**Go Mono.** In 2016, the developers of the Go programming language at Google asked us to provide free fonts for the language. To honor the anniversary of the first release of the Go language, we designed the Go Mono typeface family. It contains three weights — normal, medium, bold — in roman and italic "postures" (i.e., upright or leaning) and a serifed monospaced design with a narrow set.

## 2.6. Challenge 6: Pictograms and Symbols

As we developed the Lucida family of types, we designed pictograms and ideograms and combined them into fonts we named Lucida Icons, Arrows, and Stars. We harmonized the non-alphabetic with alphabetic fonts by equalizing the heights, proportions, and weights of the pictorial and ideographic images with those of the Lucida alphabetic faces.

In the Lucida Icons font, we included pictograms of computer paraphernalia such as floppy disks, hard drives, monitors, keyboards, mice, track balls, and tape drives. Metaphorically, we included images of file folders, mail, mailboxes, pen, pencil, brush, and text files. Various dingbats were hand signs, smile and frown faces, playing card suits, astrological signs, geometric figures, medallions, flowers, and vines.

In 1990, Microsoft licensed the Icons, Arrows, and Stars fonts and distributed them with a beta-test release of Windows 3.1. After thousands of test users liked our Icons, Arrows, and Stars fonts, Microsoft proposed to buy them outright and rename them Wingdings to go with Windows (Figure 11). We agreed. Microsoft chose to bundle only one font with Windows, however, so they selected assorted characters from each of our three fonts, assigned new mappings to the standard QWERTY keyboard, and combined them into a single font. The remaining characters from the three fonts were released in a later Font Pack as Wingdings 2 and 3.

The earliest writing systems, Sumerian cuneiform, Egyptian hieroglyphs, and Chinese characters, began with pictographic images. Those eventually evolved into abstract signs. More recently and over centuries, typography, various signs, symbols, and ornaments have been devised to supplement alphabetic texts. These graphical symbols, some called *fleurons,* others called *dingbats,* continue to be of use. In the 1970s, when pictograms were used in programming environment research at Stanford University and Xerox, they were called *icons,* the term that stuck when it appeared on the Xerox Star and Apple Macintosh. More recently, Japanese emoji, originally seen in Japanese comics and later in electronic products, are now widely popular and thousands have been included in the Unicode standard (Unicode Consortium, 2024). Our venture into pictography was just one moment in the thousands of years of ongoing evolution, sometimes forward, sometimes backward, in writing systems.

Predictably, more than three decades after Wingdings was launched, some of the objects depicted by our icons, such as the floppy disk, have become obsolete, while the abstract symbolic letters of our alphabetic fonts have remained fully functional in trillions of text exchanges over the internet. The floppy disk icon does, nevertheless, continue to be used to signify *save,* a shift of meaning from an object to a function. It has happened many times before. Few readers today see the capital "A," which acrophonically signified an ox head some 3,000 years ago in an early Semitic alphabet, as anything but an abstract sign for a vowel in various languages.

## 2.7. Challenge 7: Handwriting to Type

The first Lucida designs were responses to functional challenges, particularly resolution, but also were intended to facilitate pragmatic usage, such as programming. We were concerned with crafting designs that worked well for users of emerging technologies.

**Figure 11.** Festive sample of Wingdings, released by Microsoft in 1992.

As resolutions increased and grid-fitting technology improved, we explored the design of typefaces that could have been taken directly from handwriting into type without passing through earlier generations of typography.

**Sierra: from late humanist handwriting.** It is generally believed that our modern roman and italic types were based on the handwriting of humanist scribes of the fifteenth century, beginning with Poggio Bracciolini and Niccolò Niccoli early in the century and evolving into more calligraphic styles written by Antonio Sinibaldi and Bartolomeo Sanvito late in the century.

Holmes (the second author) experimented with twisting an edged pen to generate serifs in a late humanist style and turning that into a digital typeface for Dr.-Ing. Hell. The result is a digital typeface that is not an imitation or emulation of 15th century scribes, but an exploration of an alternate path from handwriting directly to digital (Figure 12). She named it Sierra, for the mountain range near where she grew up in California's Central Valley (Figure 13).

**Lucida Blackletter: from Burgundian Bâtarde.** Holmes had admired cursive blackletter handwriting for its dark, complex, dynamic action and chose Burgundian Bâtarde, a style of handwriting popular in the Low Countries in the 15th century and notably used by William Caxton in printing the *Canterbury Tales* in 1476, the first book printed in England. Instead of copying Caxton's type, Holmes first wrote the Bâtarde hand with an edged pen and then simplified it to attenuate its complex flourishes and make it

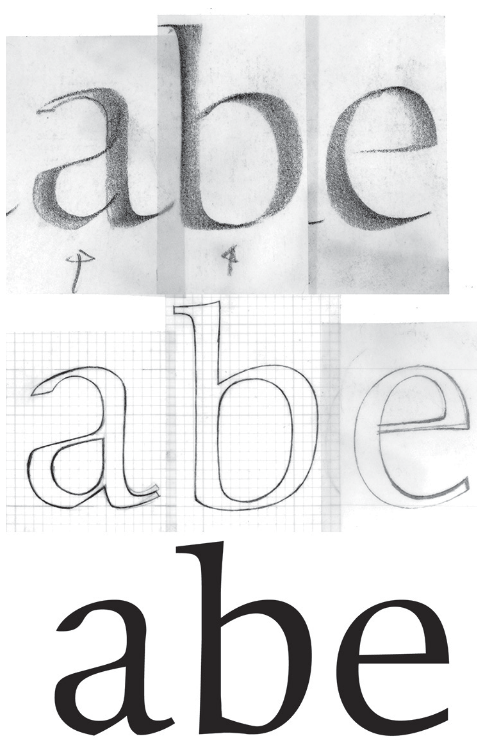


**Figure 12.** Sierra sketches by Kris Holmes for a type derived from broad-edged pen handwriting, here simulated by broad-edged pencil sketch.

abcdefghijklmnopqrstuvwxyz
ABCDEFGHIJKLMNOPQRSTUVWXYZ
*abcdefghijklmnopqrstuvwxyz*
*ABCDEFGHIJKLMNOPQRSTUVWXYZ*
**abcdefghijklmnopqrstuvwxyz**
**ABCDEFGHIJKLMNOPQRSTUVWXYZ**
***abcdefghijklmnopqrstuvwxyz***
***ABCDEFGHIJKLMNOPQRSTUVWXYZ***

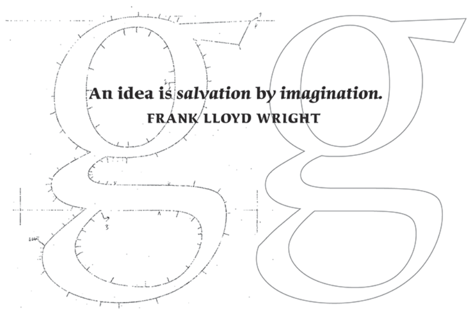



**Figure 13.** Sample of Sierra digital type family in several styles.

Whan that Aprill, with his shoures soote
The droghte of March hath perced to the roote
And bathed every veyne in swich licour,
Of which vertu engendred is the flour;
Whan Zephirus eek with his sweete breeth
Inspired hath in every holt and heeth
The tendre croppes, and the yonge sonne
Hath in the Ram his halfe cours yronne,
And smale foweles maken melodye,
That slepen al the nyght with open eye
(So priketh hem Nature in hir corages);
Thanne longen folk to goon on pilgrimages
And palmeres for to seken straunge strondes
To ferne halwes, kowthe in sondry londes;
And specially from every shires ende
Of Engelond, to Caunterbury they wende,
The hooly blisful martir for to seke
That hem hath holpen, whan that they were seeke.

**Figure 14.** Geoffrey Chaucer: General Prologue to the *Canterbury Tales.* Composed in Lucida Blackletter (Hellinga, 1982), a simplified version of the Burgundian Bâtarde type that William Caxton used in his 1476 edition of the *Canterbury Tales.*


**Figure 15.** Lucida Blackletter in a Parisian restaurant menu. The restaurant is in Paris but the menu is in Spanish for tourists. The Burgundian Bâtarde blackletter style is favored by French, Spanish, and English.

more acceptable to modern readers. The result was Lucida Blackletter, which Microsoft distributed in 1992 (Figure 14). In the U.S., the type appears more often during the winter holiday season, when blackletter types miraculously become more legible to holiday revelers, but it is used in France in other seasons as well, because the Bâtarde style was popular in handwriting and typography in the 16th century (Figure 15).

**Lucida Calligraphy: from chancery cursive.** The calligraphic hand taught by Lloyd Reynolds at Reed College was chancery cursive, a refined humanist style popular among humanist scribes working in the Vatican chancery in the 15th century. Humanist cursive was first cut in type in 1501 by Francesco Griffo and the chancery cursive was taught by Ludovico degli Arrighi and cut by Lautizio Perugino for Arrighi's book on chancery cursive printed in 1524.

Arrighi's style of chancery was revived as italic handwriting in England and America in the 20th century, and promoted on the basis of its legible letterforms and easy manual rhythm. In 1980, when Holmes reviewed Hermann Zapf's Chancery typeface for phototype by International Typeface Corporation, she delved into the history of chancery cursive in handwriting and type (Holmes, 1980).

To render Arrighi's famous hand as digital type was a daunting proposition, a conflict of elegance versus resolution. We decided to include it in the Lucida family but increased its x-height to equal that of other Lucida faces, thus enabling the central portions of the letters to contain more pixels for locally higher resolution. To compensate for the large x-height, we shortened the ascenders and descenders and widened the letters. Because chancery cursive was a favorite of calligraphers and often the only calligraphic face that people recognized easily, we named it Lucida Calligraphy (Figure 16). It was launched by Microsoft in 1992 along with other Lucida fonts in the Font Pack for Windows and has been in wide use ever since.

**Apple Chancery: chancery cursive.** In 1993, Apple asked us to design a new typeface to display the advanced capabilities of the new font technology they had just invented, TrueType GX, which could compose complex combinations of swash letters, ligatures, and context sensitive letter variations. As it happened, they showed us an example of traditional chancery cursive! Holmes proposed basing the new font directly on the italic handwriting taught by Lloyd Reynolds at Reed (Figure 17).

To create a face closer to the handwritten style of chancery that might be written by a modern scribe, Holmes gave the face luxurious ascenders and descenders, only slight slant, and narrower letters than in Lucida Calligraphy. Apple launched it as Apple Chancery and still includes it with MacOS. The face looks less like type and more like the italic handwriting written by generations of calligraphers in England, America, and elsewhere. It was even used in the menu of the wedding reception for the marriage of Prince William and Catherine Middleton in 2011.

## 2.8. Challenge 8: Connecting Scripts and Semi-Scripts

In traditional metal typesetting, connecting scripts had problems. One problem was getting the thin joining strokes to align correctly and appear to connect letters without visible gaps. Another problem was that delicate joining strokes were susceptible to battery and breakage, leaving evident gaps. There were practical restrictions on the degree of slant of script letters cast in metal.

**Lucida Handwriting.** Holmes had previously solved script joinery problems with the formal joining script of Isadora. A few years later we felt the Lucida family should have a joining script, but one like informal handwriting. The result was Lucida Handwriting, a joining script that looks like carefree, flowing handwriting (Figure 18; and analyzed in a dissertation, Figure 19). It was first distributed by Microsoft in 1992. We often see it used as a joining script as intended, but sometimes the unconnected capital letters are used in all-capital settings, where they look free and active.


**Figure 16.** Four weights of Lucida Calligraphy. It is a chancery cursive designed for screen display and laser printing in the 1990s and is still popular today. The weights vary as if the script were written with different widths of a broad-edged pen. The broader the width, the bolder the script.

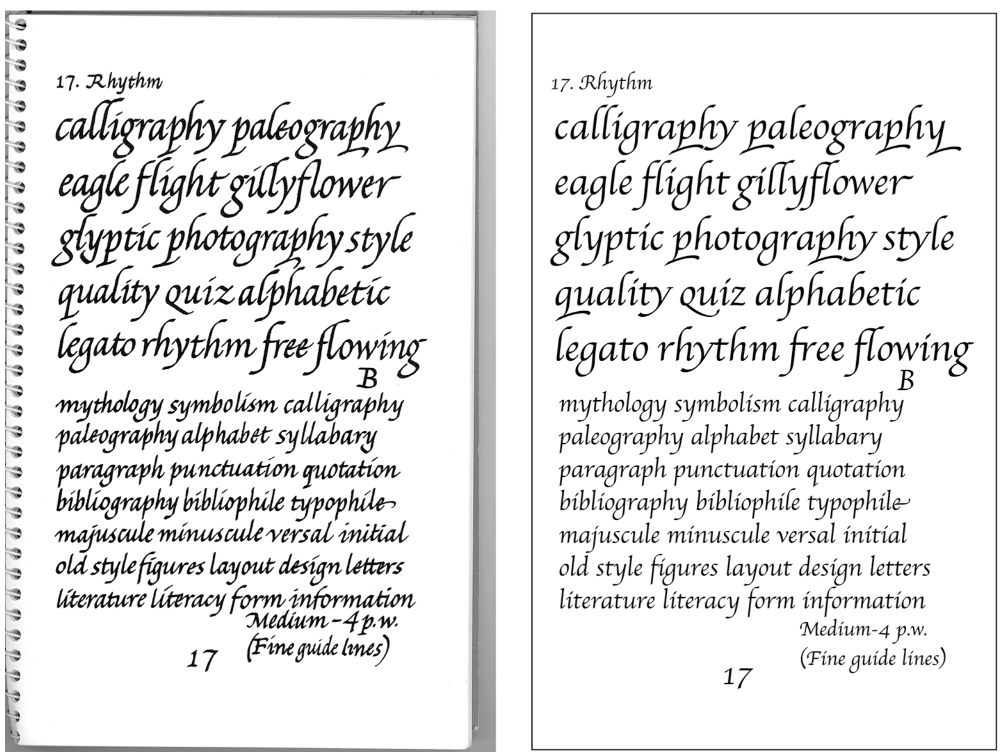



**Figure 17.** "17. Rhythm." Left page: Lloyd Reynolds' model book. Reynolds taught at Reed College where Charles Bigelow, Kris Holmes, and Steve Jobs studied. Right page: Apple Chancery, designed by Kris Holmes to express Reynolds' style of Italic handwriting as digital type.


**Figure 18.** Lucida Handwriting's connections emphasized over 16 weights, outlined.

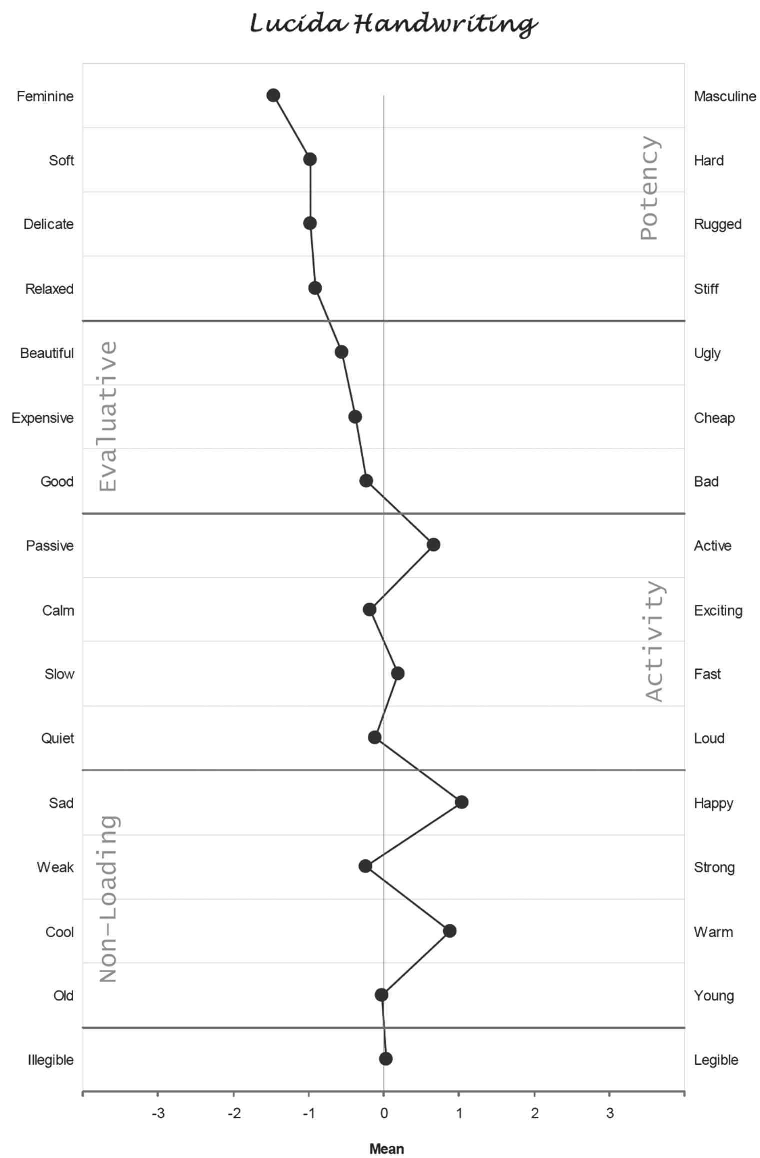



**Figure 19.** Lucida Handwriting analyzed in a Ph.D. dissertation by Audrey Dawn Shaikh at Wichita State University (Shaikh, 2007). The analysis is by a "semantic differential" psychology survey in which viewers note meanings, connotations, and feelings evoked by a typeface. Prior use of the semantic differential in typography was described by Wendt (1968) in *The Journal of Typographic Research,* which Bigelow (the first author) first read in 1968 in Jack Stauffacher's studio as a teaching assistant. (*The Journal of Typographic Research* was soon to be renamed *Visible Language.*)

Kiche Linguistics Conference

Monday, March 21, 2005

Linguistics Department Conference Room, 2122 Campbell Hall, UCLA

**Honored Guest:** ***Pedro U. Garcia Mantanic***

9:00 *Pamela Munro* **Welcome, Introductions, and Overview.**

**Figure 20.** Program of a Kiche linguistics conference, its title composed in Kolibri. The image is a Mayan rabbit scribe painting a hieroglyphic book, bound in jaguar skin — the cutest scribe of all time. Text is Lucida Bright roman, italic, and bold.

ABCDEFGHIJKLM
NOPQRSTUVWXYZ
abcdefghijklmnopqrstuvwxyz
1234567890
&@*?!

**Figure 21.** Fiorella light.

abcdefghijklmnopqrstuvwxyz
abcdefghijklmnopqrstuvwxyz
abcdefghijklmnopqrstuvwxyz
abcdefghijklmnopqrstuvwxyz
abcdefghijklmnopqrstuvwxyz
abcdefghijklmnopqrstuvwxyz
abcdefghijklmnopqrstuvwxyz
abcdefghijklmnopqrstuvwxyz
abcdefghijklmnopqrstuvwxyz
abcdefghijklmnopqrstuvwxyz
abcdefghijklmnopqrstuvwxyz
abcdefghijklmnopqrstuvwxyz
abcdefghijklmnopqrstuvwxyz
abcdefghijklmnopqrstuvwxyz
abcdefghijklmnopqrstuvwxyz

**Figure 22.** Lucida Casual in a gamut of weights.

**Kolibri.** Peter Karow, inventor of the IKARUS system, also invented a system that used context-sensitive letter variants with connecting joins at different heights, thus emulating the complex joining patterns of 18th century writing masters. Dr. Karow invited Holmes to design a script that followed his system, and she designed Kolibri for him and his firm, URW (Figure 20). The name comes from the Linnaean Latin name for the ruby-throated hummingbird, *Archilochus colubris* of Central America and the eastern United States. The hummingbird is a common character in Mayan mythology, and among other applications, Kolibri has been used in a program about the Kiche Mayan language. It was eventually produced by URW++ in the OpenType standard font format that enables context-sensitive letterform substitutions.

**Fiorella.** Fiorella is a cursive connecting script that adopts some of the subtle modulations of the Galileo typeface, but in a flowing, dynamic style. Holmes again used her joinery method from Lucida Handwriting, but Fiorella is an inclined, high-contrast style, like typefaces used in fashion advertising and elegant contexts, but with greater action and liveliness than is seen in strict cursive styles (Figure 21).

**Lucida Casual.** After we saw that Lucida Handwriting was popular following its release in 1992, we explored another direction, a semi-script text face that would have proportions and weights similar to the original Lucida, but that would be relaxed and curvilinear instead of rigid and rectilinear, like rapid handwriting with a partly worn felt-tip marker. The result was Lucida Casual in roman and italic styles, which was soon distributed with popular ink-jet printers by Hewlett Packard (Figure 22). Despite their modern origins, they evoked a distant echo of 15th century humanist fast handwriting with a worn nib.

**Textile.** Shortly after Lucida Casual appeared, Apple asked us to design a fun-loving all-curves font to contrast with the rigid, retro-futuristic look of Chicago, which signified Macintosh to many users because of its geometric-engineered insouciance. We were aware of every feature of Chicago because we had digitally constructed the TrueType outline version of it, using only straight lines and circular arcs, for Apple System 7 in 1990–1991. We felt that what Apple wanted was a sumo wrestler version of Lucida Casual, but Apple decreed that must fit into the same constrained metric space as Chicago. A daunting task, but we were inspired by a remark attributed to Mark Twain: “A round man cannot be expected to fit in a square hole right away. He must have time to modify his shape.” Hence, we took some time for Apple. The result was Textile — big, brawny, and bold (Figure 23). Apple no longer distributes it with MacOS, but it is still available as Lucida Marker.

## 2.9. Challenge 9: Mathematical Symbols

When we designed the first Lucida fonts, we designed mathematical symbols for them to be used with the TeX system invented by Stanford computer scientist Donald Knuth


**Figure 23.** Apple Textile (or Lucida Marker) on a vitamin package. After a typeface is launched, its designers cannot predict or control how it will be used — from computer operating system to vitamin box.

for composing mathematics. With TeX, Professor Knuth invented Metafont, a digital type system for developing fonts for mathematics, particularly the Computer Modern family that emulated Monotype's "Modern" fonts that had been used for typesetting mathematics in hot-metal composing machines for several decades.

Our goal was to provide a set of fonts in a different type style for TeX. To harmonize the mathematical characters with our original Lucida faces, we designed the mathematical fonts to be sturdy and resistant to noise in low-resolution printing and faxing. However, they were not intended for high-resolution book printing, and one editor called them "too aggressively legible." Taking that as guidance when we designed Lucida Bright for *Scientific American,* we "bright-ized" the Lucida Math fonts to harmonize with Lucida Bright alphabetic fonts. Microsoft released the bright versions along with other Lucida fonts in 1992, but the character encodings in that release made them difficult to use with TeX. Later, we reworked the character encodings, added more characters, and a small independent firm Y&Y produced them in PostScript Type 1 font format specifically for use with TeX in 1993.

In 2011, the TeX Users Group (TUG) asked us to make new versions of Lucida Math fonts for OpenType font technology and add more characters in the process. This we did, with help from TUG in producing the fonts (Figure 24). We took the opportunity to re-design some characters with different proportions and sizes. Our OpenType math fonts have been in use for more than a dozen years, while the older PostScript fonts have become technically obsolete.

There appears to be no end to the making of math fonts as long as there are creative mathematicians who think up new mathematical concepts that require new symbols. Therefore, from time to time, we are asked to add new or variant characters to our math fonts. It seems that the invention of new symbols has no end.

## 2.10. Challenge 10: A Reversal — From Low to High Resolution Fonts

In 1988, Apple Computer came to us with an unusual task. Instead of designing outline fonts like Lucida that technology can convert to legible bitmap fonts, they asked us to do the reverse: convert four of their bitmap "City" fonts from bitmap format to TrueType outline format — the new, high-resolution outline font technology that Apple was developing (Figure 25).

The four low-resolution bitmap fonts, which had been designed by Susan Kare at Apple and were familiar to all Macintosh users, were Geneva, New York, Monaco, and Chicago. At 12 point on the Macintosh screen with a resolution of only 72 pixels per inch, those fonts were only 12 pixels in height, with an extra pixel or two for accents. Apple's TrueType font technology had a resolution of 2,048 possible points vertically and horizontally, so Apple was asking us to increase their bitmap fonts resolution by 150 times. Mere multiplication of size magnification was not appropriate because the result would be grotesquely blocky letters made of huge square pixel blocks instead of the smooth traditional letter shapes expected by readers.

What we did instead was deduce the kinds of high-resolution outline fonts from which those rudimentary bitmap fonts might have been rasterized. We thus inverted the *bottom-up* job into a *top-down* task by inference. Modern trackers and paleontologists

### 4 Application

We consider here the applications of Theorems 5.1 and 5.2 to a complete multipartite graph $K_{n_1 \ldots n_p}$. It can be shown that the number of spanning trees of $K_{n_1 \ldots n_p}$ may be written

$$T = n^{p-2} \prod_{i=1}^{p} (n - n_i)^{n_i - 1} \tag{19}$$

where

$$n = n_1 + \cdots + n_p. \tag{20}$$

It follows from Theorems 5.1 and 5.2 that

$$\begin{aligned} H_c = {} & \frac{1}{2n} \sum_{l=0}^{n} (-1)^l (n-l)^{p-2} \sum_{l_1 + \cdots + l_p = l} \prod_{i=1}^{p} \binom{n_i}{l_i} \\ & \cdot [(n-l) - (n_i - l_i)]^{n_i - l_i} \cdot \left[ (n-l)^2 - \sum_{j=1}^{p} (n_i - l_i)^2 \right]. \end{aligned} \tag{21}$$

`... \binom{n_i}{l _i}\\`

and

$$\begin{aligned} H_c = {} & \frac{1}{2} \sum_{l=0}^{n-1} (-1)^l (n-l)^{p-2} \sum_{l_1 + \cdots + l_p = l} \prod_{i=1}^{p} \binom{n_i}{l_i} \\ & \cdot [(n-l) - (n_i - l_i)]^{n_i - l_i} \left( 1 - \frac{l_p}{n_p} \right) [(n-l) - (n_p - l_p)]. \end{aligned} \tag{22}$$

The enumeration of $H_c$ in a $K_{n_1 \cdots n_p}$ graph can also be carried out by Theorem 7.2 or 7.3 together with the algebraic method of (2). Some elegant representations may be obtained. For example, $H_c$ in a $K_{n_1 n_2 n_3}$ graph may be written

$$\begin{aligned} H_c = {} & \frac{n_1! n_2! n_3!}{n_1 + n_2 + n_3} \sum_i \left[ \binom{n_1}{i} \binom{n_2}{n_3 - n_1 + i} \binom{n_3}{n_3 - n_2 + i} \right. \\ & \left. + \binom{n_1 - 1}{i} \binom{n_2 - 1}{n_3 - n_1 + i} \binom{n_3 - 1}{n_3 - n_2 + i} \right]. \end{aligned} \tag{23}$$

**Figure 24.** Lucida Math demonstration, courtesy of the TeX Users Group.

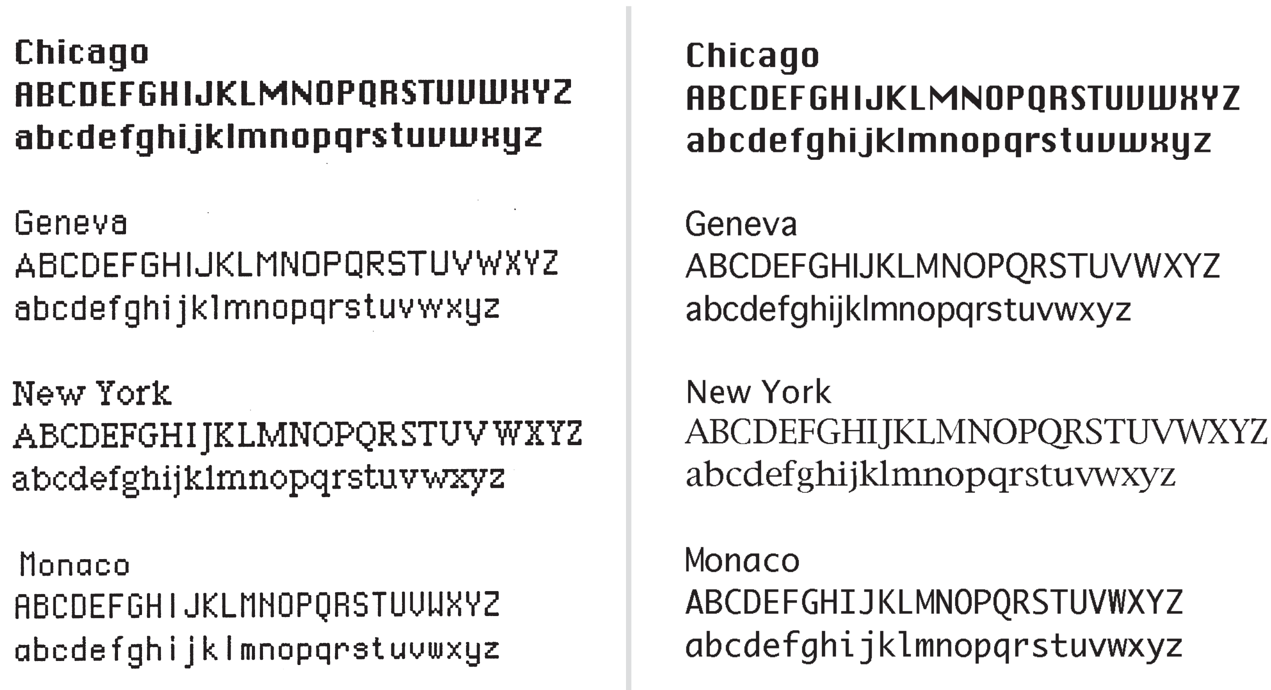



**Figure 25.** A scan of the original Macintosh City fonts at 12 points, designed by Susan Kare (left), compared with the TrueType 24-point versions (right).

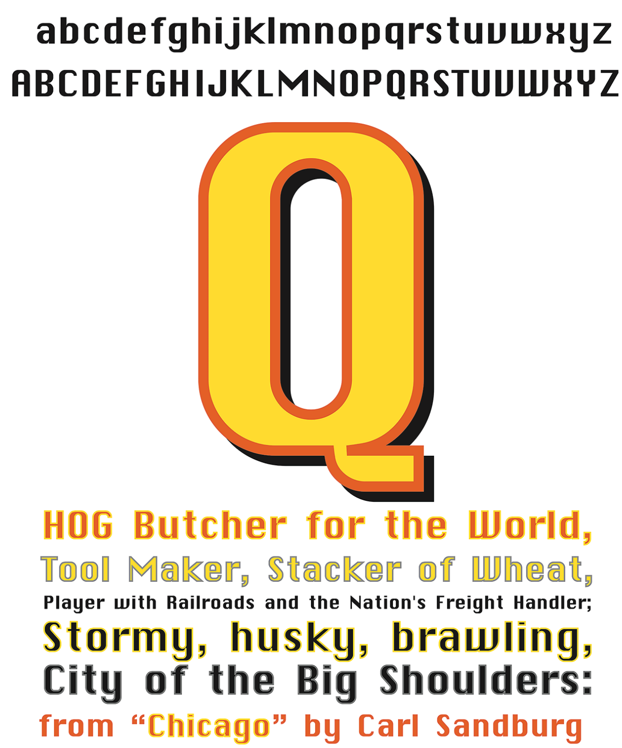



**Figure 26.** Chicago font in TrueType, 1991, showing its scalability, versatility, and color adaptability as a display face — no longer limited to a single size on the Macintosh screen.

do this when deducing what kind of animal left certain fossilized footprints. Semioticians might call it going from index to icon. Our task was complicated because each bitmap screen size was different in style and proportion, depending on Apple's original designer's visual intuition. Hence, we used statistics to estimate sizes, weights, and proportions. Moreover, none of the original bitmaps emulated a specific typeface. Generically, New York was serifed, Geneva was sans-serif, Monaco was monospaced sans-serif, and Chicago was bold condensed sans-serif (Bigelow & Holmes, 1991).

To avoid apparent changes in font size when used together at the same point size on the Macintosh, and to increase the number of pixels in the base forms, we made all x-heights proportionally large with equal ascender and descender lengths for New York, Geneva, and Monaco. We gave Chicago a larger x-height in keeping with its use as a headline face on the classical Macintosh screen (Figure 26). At high resolution, the faces took on clearer stylistic identities. New York looked like a mid-16th century French face, except with huge x-height. Geneva looked like a sans-serif grotesque in Swiss style. Monaco was a monospaced face with a slightly lively hieroglyphic look due to distinct serifs on letters "i," "j," and "l."

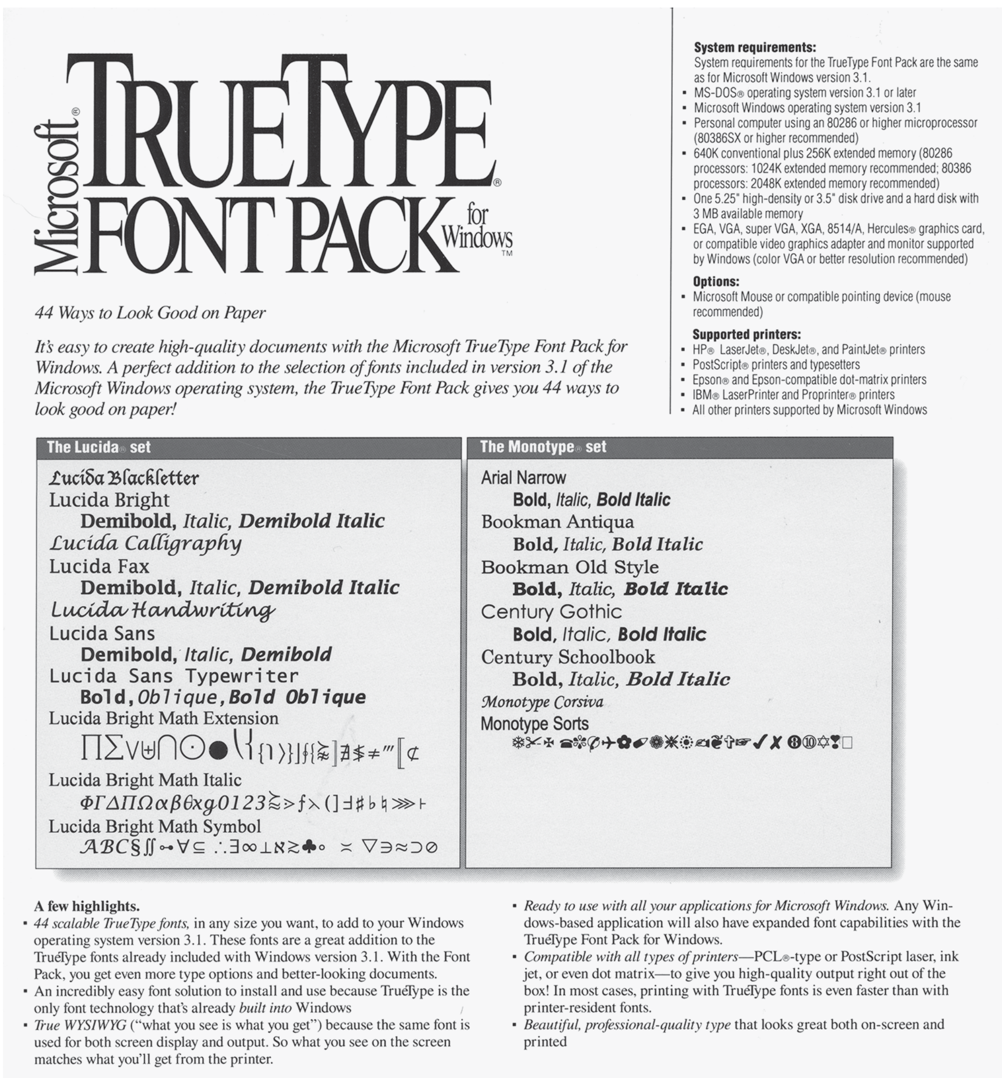
These four fonts were released in 1991 with Apple's then revolutionary System 7 operating system, which included TrueType font technology.

## 2.11. Challenge 11: Latin and Non-Latin Alphabets

Non-Latin scripts and writing systems were often difficult to adapt to traditional analog font technology. To Western eyes, not only were non-Latin character shapes novel and diverse, but their names and systematics were unfamiliar. Beginning in the 1980s, dedicated scholars and technologists have labored to devise and develop a single, universal standard for the computer encoding of characters for worldwide information exchange. The result of their decades of labor is the Unicode standard, now in its 16th edition and comprising some 155,000 characters and 170 scripts. The clarity and utility of the standard has enabled type designers to address issues of legibility, expressiveness, clarity, and style without also grappling with the fundamental issues of nomenclature and systematics that have been resolved and codified by Unicode.

*Encoding* as used here means the numerical identifiers by which computers denote characters. For instance, the capital "A" character in English and other Latin-based alphabets of Western European languages is identified as Unicode "code point" 0041, and lowercase "a" is 0061, in hexadecimal numbering. In ASCII, using decimal numbering, capital "A" is encoded as decimal 65 and lowercase "a" is decimal 97. What is important about a standard encoding is that someone can type the letter "A" on a computer keyboard in, say, Minneapolis, Minnesota, and it can be encoded in text transmitted over the internet through a series of different computer servers and systems and arrive on the screen of a different brand of computer and operating system in Bangalore, India, and still be the letter "A." The same is now true for around 150,000 other characters standardized in Unicode, from English to Hindi to Chinese.

In 1989, Microsoft and Apple agreed on a new digital font format called TrueType, in which all characters would be encoded with the Unicode standard. The Lucida fonts in the Microsoft Font Pack for Windows released in 1992 were encoded with Unicode (Figure 27). The engineers at Microsoft then asked us to make a font that contained Latin plus non-Latin and symbol character sets, to demonstrate the power and flexibility of the TrueType font format. The result was based on Lucida Sans and was released as Lucida Sans Unicode in 1993. It contains around 1,725 letters and characters for the languages of Europe and the Americas that use the Latin alphabet, including deriva-



Microsoft® TRUETYPE® FONT PACK for Windows™

*44 Ways to Look Good on Paper*

*It's easy to create high-quality documents with the Microsoft TrueType Font Pack for Windows. A perfect addition to the selection of fonts included in version 3.1 of the Microsoft Windows operating system, the TrueType Font Pack gives you 44 ways to look good on paper!*

**System requirements:**
System requirements for the TrueType Font Pack are the same as for Microsoft Windows version 3.1.
- MS-DOS® operating system version 3.1 or later
- Microsoft Windows operating system version 3.1
- Personal computer using an 80286 or higher microprocessor (80386SX or higher recommended)
- 640K conventional plus 256K extended memory (80286 processors: 1024K extended memory recommended; 80386 processors: 2048K extended memory recommended)
- One 5.25" high-density or 3.5" disk drive and a hard disk with 3 MB available memory
- EGA, VGA, super VGA, XGA, 8514/A, Hercules® graphics card, or compatible video graphics adapter and monitor supported by Windows (color VGA or better resolution recommended)

**Options:**
- Microsoft Mouse or compatible pointing device (mouse recommended)

**Supported printers:**
- HP® LaserJet®, DeskJet®, and PaintJet® printers
- PostScript® printers and typesetters
- Epson® and Epson-compatible dot-matrix printers
- IBM® LaserPrinter and Proprinter® printers
- All other printers supported by Microsoft Windows

**The Lucida® set**

Lucida Blackletter
Lucida Bright
**Demibold,** *Italic,* ***Demibold Italic***
*Lucida Calligraphy*
Lucida Fax
**Demibold,** *Italic,* ***Demibold Italic***
*Lucida Handwriting*
Lucida Sans
**Demibold,** *Italic,* ***Demibold***
Lucida Sans Typewriter
**Bold,** *Oblique,* ***Bold Oblique***
Lucida Bright Math Extension
∏∑⋁⊎⋂⊙●
Lucida Bright Math Italic
ΦΓΔΠΩαβθxg0123
Lucida Bright Math Symbol
𝒜ℬ𝒞§∬⊶∀⊆ ∴∃∞⊥ℵ≳♣∘ ≍ ∇∋≈⊃⊘

**The Monotype® set**

Arial Narrow
**Bold,** *Italic,* ***Bold Italic***
Bookman Antiqua
**Bold,** *Italic,* ***Bold Italic***
Bookman Old Style
**Bold,** *Italic,* ***Bold Italic***
Century Gothic
**Bold,** *Italic,* ***Bold Italic***
Century Schoolbook
**Bold,** *Italic,* ***Bold Italic***
*Monotype Corsiva*
Monotype Sorts

**A few highlights.**
- *44 scalable TrueType fonts,* in any size you want, to add to your Windows operating system version 3.1. These fonts are a great addition to the TrueType fonts already included with Windows version 3.1. With the Font Pack, you get even more type options and better-looking documents.
- An incredibly easy font solution to install and use because TrueType is the only font technology that's already *built into* Windows
- *True WYSIWYG* ("what you see is what you get") because the same font is used for both screen display and output. So what you see on the screen matches what you'll get from the printer.
- *Ready to use with all your applications for Microsoft Windows.* Any Windows-based application will also have expanded font capabilities with the TrueType Font Pack for Windows.
- *Compatible with all types of printers*—PCL®-type or PostScript laser, ink jet, or even dot matrix—to give you high-quality output right out of the box! In most cases, printing with TrueType fonts is even faster than with printer-resident fonts.
- *Beautiful, professional-quality type* that looks great both on-screen and printed

**Figure 27.** Twenty-two original Lucida digital typefaces designed by Bigelow & Holmes for the TrueType digital font technology invented by Apple and adopted by Microsoft.

1 ΑΒΓΔΕΖΗΘΙΚΛΜΝΞΟΠΡΣΤΥΦΧΨΩ
2 αβγδεζηθικλμνξοπρστυφχψω
3 ΑΒΓΔΕΖΗΘΙΚΛΜΝΞΟΠΡΣΤΥΦΧΨΩ
4 αβγδεζηθικλμνξοπρστυφχψω
5 ΑΒΓΔΕΖΗΘΙΚΛΜΝΞΟΠΡΣΤΥΦΧΨΩ
6 αβγδεζηθικλμνξοπρστυφχψω
7 ΑΒΓΔΕΖΗΘΙΚΛΜΝΞΟΠΡΣΤΥΦΧΨΩ
8 αβγδεζηθικλμνξοπρστυφχψω
9 ΑΒΓΔΕΖΗΘΙΚΛΜΝΞΟΠΡΣΤΥΦΧΨΩ
10 αβγδεζηθικλμνξοπρστυφχψω
11 ΑΒΓΔΕΖΗΘΙΚΛΜΝΞΟΠΡΣΤΥΦΧΨΩ
12 αβγδεζηθικλμνξοπρστυφχψω
13 АБВГДЕЖЗИЙКЛМНОПРСТУФХЦЧШЩЪЫЬЭЮЯ
14 абвгдежзийклмнопрстуфхцчшщъыьэюя
15 АБВГДЕЖЗИЙКЛМНОПРСТУФХЦЧШЩЪЫЬЭЮЯ
16 абвгдежзийклмнопрстуфхцчшщъыьэюя
17 АБВГДЕЖЗИЙКЛМНОПРСТУФХЦЧШЩЪЫЬЭЮЯ
18 абвгдежзийклмнопрстуфхцчшщъыьэюя
19 АБВГДЕЖЗИЙКЛМНОПРСТУФХЦЧШЩЪЫЬЭЮЯ
20 абвгдежзийклмнопрстуфхцчшщъыьэюя
21 АБВГДЕЖЗИЙКЛМНОПРСТУФХЦЧШЩЪЫЬЭЮЯ
22 абвгдежзийклмнопрстуфхцчшщъыьэюя
23 АБВГДЕЖЗИЙКЛМНОПРСТУФХЦЧШЩЪЫЬЭЮЯ
24 абвгдежзийклмнопрстуфхцчшщъыьэюя
25 אבגדהוזחטיךכלםמןנסעףפץצקרשת
26 אבגדהוזחטיךכלםמןנסעףפץצקרשת
27 ɐɑɒɓɔɕɖɗɘəɚɛɜɝɞɟɠɡɢɣɤɥɦɧɨɩɪɫɬɭɮɯ
28 ɰɱɲɳɴɵɶɷɸɹɺɻɼɽɾɿʀʁʂʃʄʅʆʇʈʉʊʋ
29 ʌʍʎʏʐʑʒʓʔʕʖʗʘʙʚʛʜʝʞʟʠʡʢʣʤʥʦʧʨ
30 กขฃคฅฆงจฉชซฌญฎฏฐฑฒณดตถ
31 ทธนบปผฝพฟภมยรฤลฦวศษสหฬอฮ
32 ابتثجحخدذرزسشصضطظعغفقكلمنهوي
33 ابةتثجحخدذرزسشصضطظعغفقكلمنهوي
34 ابةتثجحخدذرزسشصضطظعغفقكلمنهوي
35 अआइईउऊऋऌऍऎएऐऑऒओऔकखगघङचछ
36 जझञटठडढणतथदधनऩपफबभमयरऱलळऴवशषसह
37 अआइईउऊऋऌऍऎएऐऑऒओऔकखगघङचछ
38 जझञटठडढणतथदधनऩपफबभमयरऱलळऴवशषसह

**Figure 28.** The authors' non-Latin typeface designs, showing only normal weights, in serif and sans-serif styles, and proportional and monospaced versions. Italics and bold weights have been omitted. Not all faces have all variants.

**1–12.** Greek (in pairs): sans-serif regular; sans-serif narrow; sans-serif monospaced; sans-serif monospaced narrow; sans-serif Console; serifed Bright.

**13–24.** Cyrillic (in pairs): sans-serif regular; sans-serif narrow; sans-serif monospaced; sans-serif monospaced narrow; sans-serif Console; serifed Bright.

**25–26.** Hebrew: sans-serif regular; sans-serif monospaced.

**27–29.** International Phonetic Alphabet (IPA), sans-serif.

**30–31.** Thai, sans-serif.

**32–34.** Arabic: sans-serif regular; sans-serif monospaced; Naskh (thick-thin).

**35–38.** Devanagari (Hindi, Sanskrit, other languages): sans-serif, proportional, and monospaced.

**Figure 29.** A sequence of still cells for an animated run cycle of an "H," mapped against a similar run cycle for a human figure — from Kris Holmes' lecture "Moving Right Along," on the occasion of her receipt of the RIT Frederic W. Goudy Award in typography in 2012.

tives for languages of Africa, as well as letters for Greek, Cyrillic, and Hebrew writing systems, and for the International Phonetic Alphabet (Bigelow & Holmes, 1993).

Additionally, the font includes an extensive set of mathematical, graphical, and other signs and symbols. All were designed to have similar sizes, proportions, weights, and features, so that the disparate scripts and signs are united by a common, underlying graphical style. The non-Latin alphabets, like the Latin alphabets, were harmonized with Lucida Sans, not only for graphical harmony but also because of a long-standing belief by modernists in the 20th century that sans-serif designs can help neutralize features which otherwise may impede international communication, favoring some historical or cultural features over others. Although initially intended to show the benefits of TrueType and Unicode in 1993, it continues to be distributed with Windows operating systems.

Our subsequent work for Apple and other firms extended our designs of non-Latin typefaces to Greek, Cyrillic, Hebrew, Arabic, Devanagari (Hindi, Sanskrit), Thai, and International Phonetic (Figure 28). In 2000, we incorporated most of those non-Latin faces along with additional Latin and symbol characters into Lucida Grande, a pair of Unicode based TrueType fonts that Apple established as system fonts in the OS X operating system.

**Non-latin monospaced, a retro-challenge.** Although high-technology companies prefer to advertise progress, many of them require monospaced, typewriter-like fonts in operating systems and applications, so we were often asked to design monospaced versions of non-Latin typefaces to accompany or supplement our Latin monospaced fonts. Greek and Cyrillic monospaced alphabets are not only used alone. Our Lucida Grande Mono and Lucida Console fonts automatically include Greek and Cyrillic monospaced alphabets, and we have also designed monospaced Arabic, Hebrew, and Devanagari fonts (Figure 28).

### 2.12. Challenge 12: Animated Fonts

The internet offers a surfeit of winking, blinking, and nodding letters that are trivial to produce and even less informative to witness, but in the golden age of American cartoons, animators often made letters look alive.

In an acceptance lecture for the Frederic W. Goudy Award at the RIT international symposium "Reading Digital," Holmes (the second author) spoke not of static but of dynamic typefaces. Using examples of her work and that of others, she demonstrated how digital technology and the internet enable type to enter a third dimension, not of space but of time, when letters come to life (Figure 29). She showed that typographic characters can be transformed in truly animated characters by using classic animation techniques including "squash and stretch," "anticipation and overshoot," "easy in, easy out," and self-writing script, among others, as seen in Looney Tunes and other classic cartoons.

"That's all, folks!"

## 3. References

Bigelow, C. (1979). On type: Galliard [Review]. *Fine Print, 5*(1).

Bigelow, C. (1985). Introduction. *Visible Language, 19*(1), 5–10.

Bigelow, C. (1986). Principles of type design for the personal workstation. *Gutenberg-Jahrbuch, 61*, 253–270.

Bigelow, C., & Day, D. (1983). Digital typography. *Scientific American, 249*(2), 106–119.

Bigelow, C., & Holmes, K. (1986). The design of Lucida: An integrated family of types for electronic literacy text processing and document manipulation. In J. C. Van Vliet (Ed.), *Text processing and document manipulation* (pp. 1–17). Cambridge University Press.

Bigelow, C., & Holmes, K. (1991). Notes on Apple 4 fonts. *Electronic Publishing, 4*(3), 171–181.

Bigelow, C., & Holmes, K. (1993). The design of a Unicode font. *Electronic Publishing, 6*(3), 999–1015.

Bigelow, C., & Holmes, K. (2018). Science and history behind the design of Lucida. *TUGboat, 39*(3), 901–908.

Bigelow, C., & Seybold, J. (1981). Technology and the aesthetics of type: Maintaining the "tradition" in the age of electronics. *The Seybold Report, 10*(24).

Bigelow, C., & Seybold, J. (1982a). The principles of digital type: Quality type for low, medium and high resolution printers. *The Seybold Report, 11*(8).

Bigelow, C., & Seybold, J. (1982b). The principles of digital type: Quality type for low, medium and high resolution printers. *The Seybold Report, 11*(12).

Bowden, P. R., & Brailsford, D. F. (1989). On the noise immunity and legibility of Lucida fonts. In J. André & R. D. Hersch (Eds.), *Electronic publishing, artistic imaging, and digital typography* (pp. 205–212). Springer-Verlag.

Deewan, N. (2022). *Lucida Console*. Klever.

Hellinga, L. (1982). *Caxton in focus.* The British Library.

Holmes, K. (1980). ITC Zapf Chancery. *Fine Print, 6.*

Holmes, K. (1985). Terpsichore and typography. *Fine Print.*

Holmes, K. (2015). *Remembering Hermann Zapf* [Blog post]. https://bigelowandholmes.typepad.com/bigelow-holmes/2015/06/remembering-hermann-zapf.html

Jacobs, M. (1958). *Clackamas-Chinook texts.* Indiana University Research Center in Anthropology, Folklore, and Linguistics.

Karow, P. (1998). Two decades of typographic research at URW: A retrospective. In R. D. Hersch, J. André, & H. Brown (Eds.), *Electronic publishing, artistic imaging, and digital typography* (pp. 265–280). Springer-Verlag.

Karow, P. (2019). *Pioneering years: History of URW, Part 1*. URW Publishing Department.

Kay, A. C. (1977). Microelectronics and the personal computer. *Scientific American, 237*(3), 230–245.

Morris, R. A. (1989). Rendering digital type: A historical and economic view of typography. *The Computer Journal, 32*(6), 524–532.

Morris, R. A., Aquilante, K., Yager, D., & Bigelow, C. (2002). P-13: Serifs slow RSVP reading at very small sizes, but don't matter at larger sizes. *SID Symposium Digest of Technical Papers, 33*(1), 244–247.

Schulz-Anker, E. (1970). Syntax-Antiqua, a sans serif on a new basis. *Gebrauchsgraphik, 7.*

Shaikh, A. D. (2007). *Psychology of onscreen type: Investigations regarding typeface personality, appropriateness, and impact on document perception* [Ph.D. disseration]. Wichita State University.

Smith, A. R. (2021). *A biography of the pixel*. MIT Press.

Unicode Consortium (2024). *The Unicode Standard, version 16.0.0.* The Unicode Consortium.

Wendt, D. (1968). Semantic differentials of typefaces as a method of congeniality research. *The Journal of Typographic Research, 2*(1), 3–25.

Zapf, H. (2000). *Vom stempelschnitt zur digitalisierung von schriftzeichen. Die technischen veränderungen der schriftherstellungen.* Gutenberg-Gesellschaft.

## Authors

**Charles Bigelow** is a typographer, educator, MacArthur Prize Fellow, and RIT Goudy Award recipient, who has taught at Stanford, RIT, and RISD. He organized pioneering conferences on digital typography and reading science, and co-designed the Lucida typeface family. A former president of ATypI's Committee on Letterform Research, he holds degrees from Reed College and UCLA and studied with Lloyd Reynolds, Hermann Zapf, and Jack Stauffacher. He has consulted for Apple, Microsoft, and Adobe, among others.

**Kris Holmes** is a type designer, calligrapher, and animator known for co-creating the Lucida typeface family. She has designed over 300 typefaces, including Apple Chancery and Wingdings, and her work appears in *Scientific American* and in widely available Unicode fonts. A Goudy Award recipient, she studied with Hermann Zapf, Lloyd Reynolds, Robert Palladino, Edward Catich, and Ed Benguiat, and holds degrees from Harvard and UCLA. Her calligraphy is held in the Klingspor Museum and RIT's Cary Collection. She has taught at RISD, RIT, and University of the Arts, and she created the award-winning animated film *La Bloomba.*