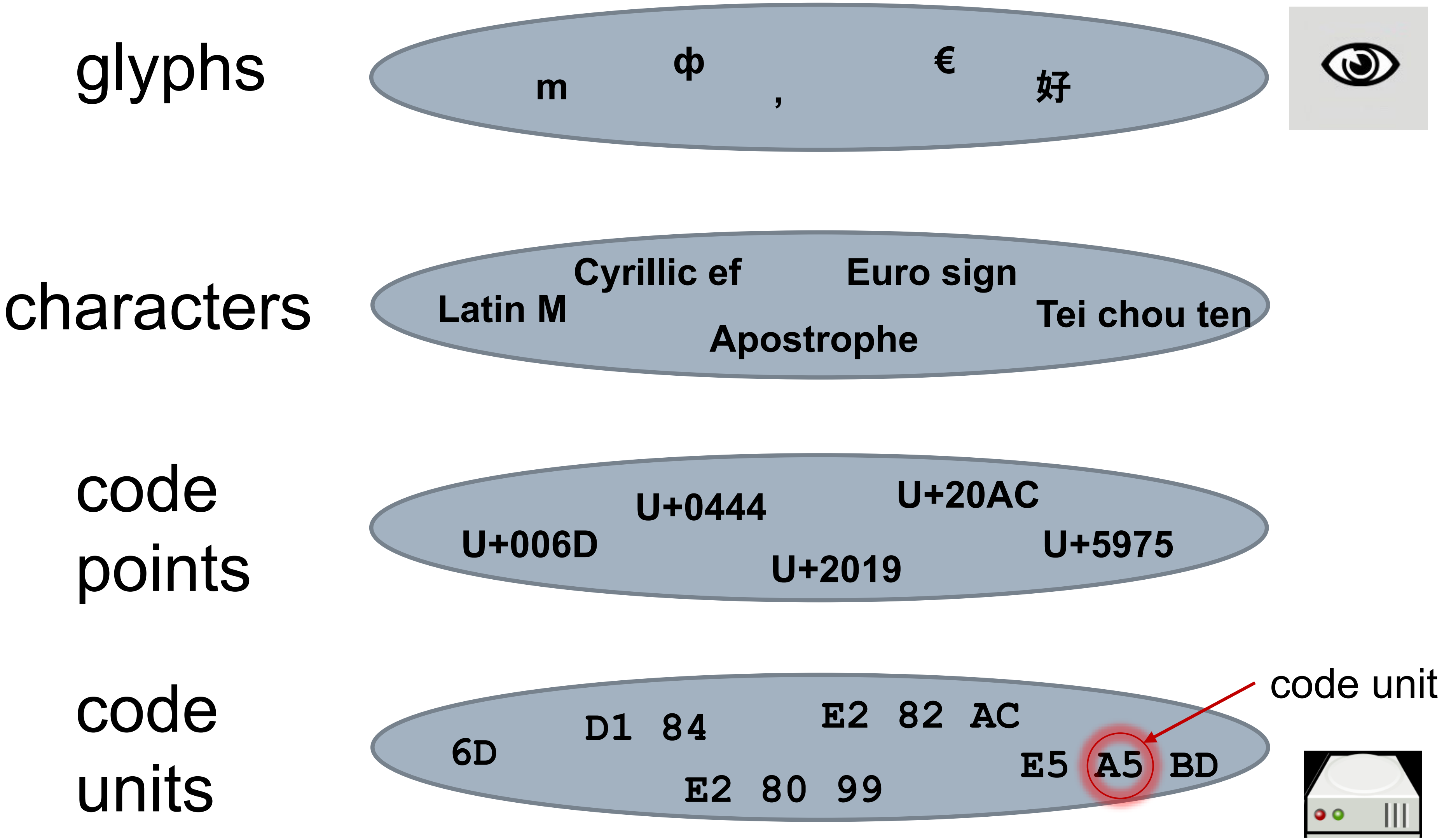
# Unicode and UTF-8

Lecture 33

A standard for the discrete representation of written text

# The Big Picture



glyphs

m ф ’ € 好

characters

Latin M Cyrillic ef Apostrophe Euro sign Tei chou ten

code points

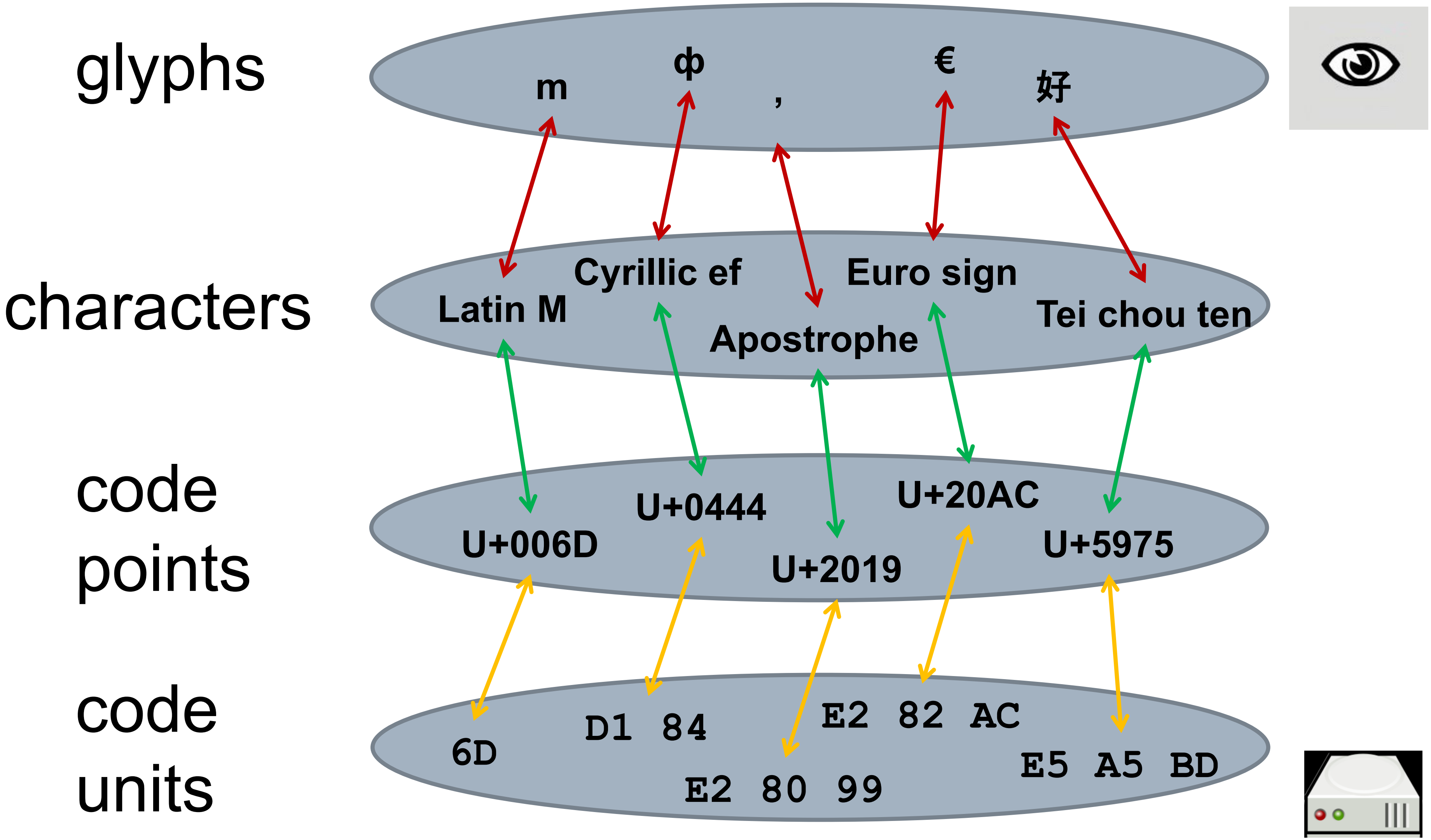
U+006D U+0444 U+2019 U+20AC U+5975

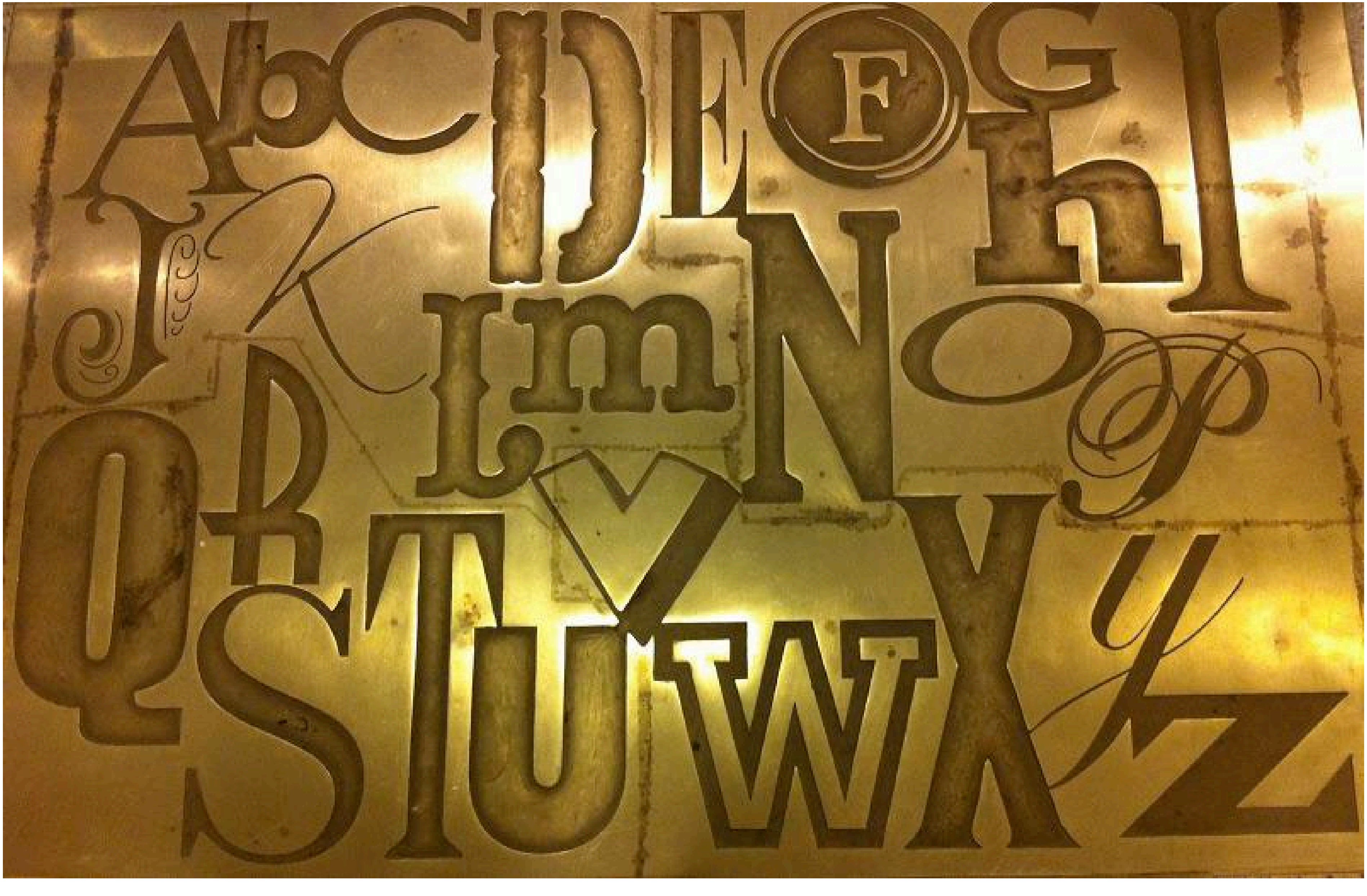
code units

```
6D   D1 84   E2 80 99   E2 82 AC   E5 A5 BD
```

code unit

# The Big Picture



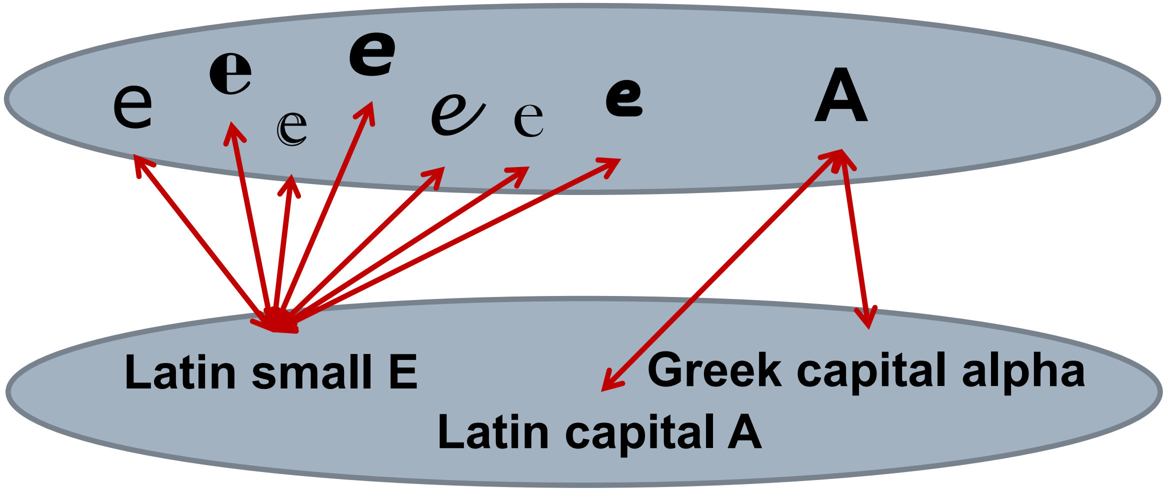

AbCDEFGhI
JKLmNOP
QRSTUVWXyZ

# Text: A Sequence of Glyphs

- Glyph: “An individual mark on a written medium that contributes to the meaning of what is written.”
  - See foyer floor in main library
- One *character* can have many *glyphs*
  - Example: Latin E can be e, ***e***, e, **e**, e, **e**, *e*…
- One *glyph* can be different *characters*
  - A is both (capital) Latin A and Greek Alpha
- One unit of text can consist of *multiple* glyphs
  - An accented letter (é) is two glyphs
  - The ligature of f+i (ﬁ) is two glyphs

# Glyphs vs Characters

glyphs



Latin small E

Greek capital alpha

Latin capital A

characters

# Security Issue

- Visual homograph: Two different characters that look the same
  - Would you click here: www.paypal.com ?

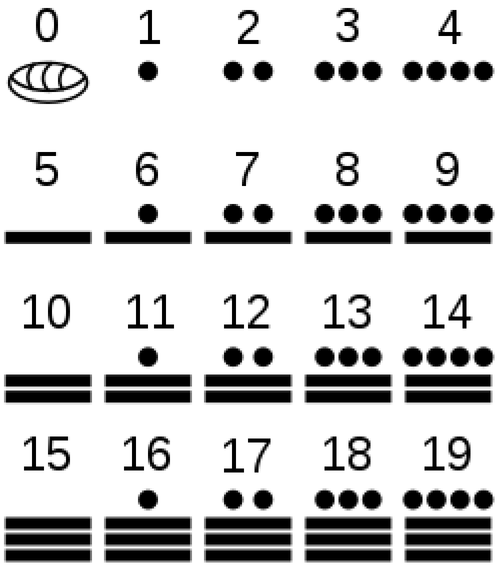
# Security Issue

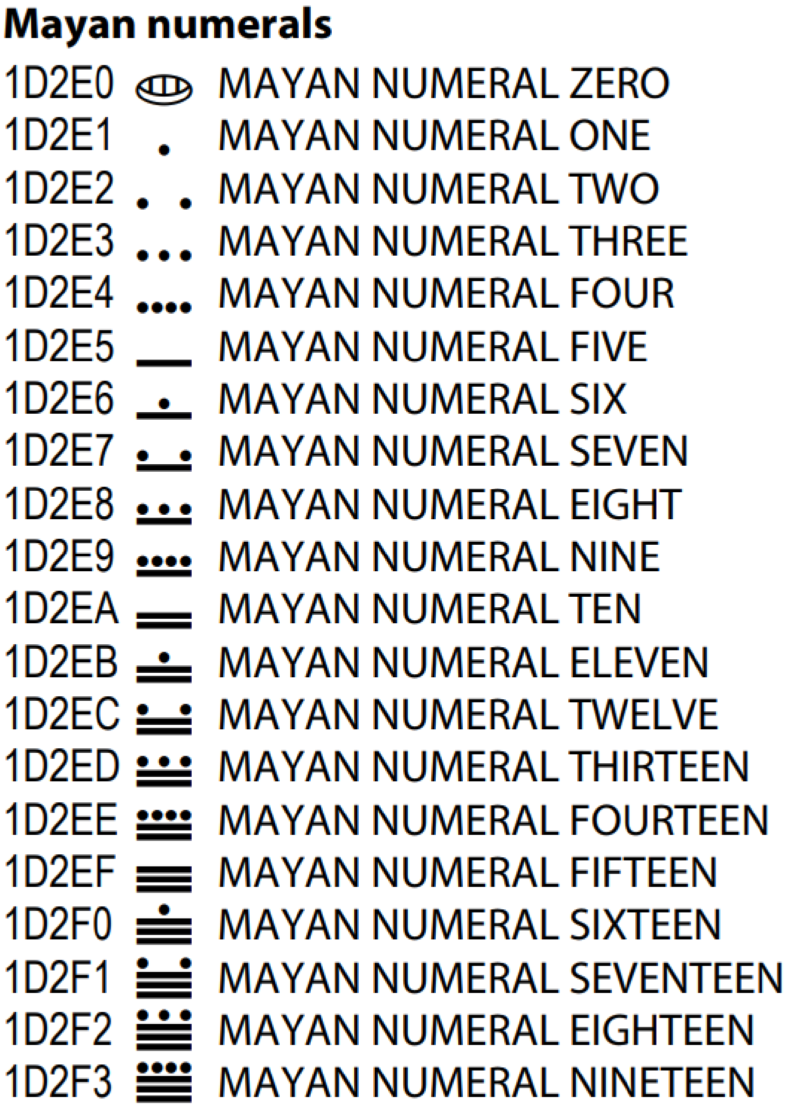
- Visual homograph: Two different characters that look the same
  - Would you click here: www.paypal.com ?
  - Oops! The second ‘a’ is actually CYRILLIC SMALL LETTER A
  - This site successfully registered in 2005
- Other examples: combining characters
  - ñ = LATIN SMALL LETTER N WITH TILDE
  - ñ = LATIN SMALL LETTER N + COMBINING TILDE
- “Solution”
  - Heuristics that warn users when languages are mixed and homographs are possible

# Unicode Code Points

- Each character is assigned a unique *code point*
- A code point is defined by an integer value, and is also given a name
  - one hundred and nine (109, or 0x6d)
  - LATIN SMALL LETTER M
- Convention: Write code points as U+hex
  - Example: U+006D
- As of Sept 2022, v15 (see unicode.org):
  - Contains 149,186 code points  
    emoji-versions.html
  - Covers 161 scripts (and counting…)  
    unicode.org/charts/

# Example Recent Addition (v11)

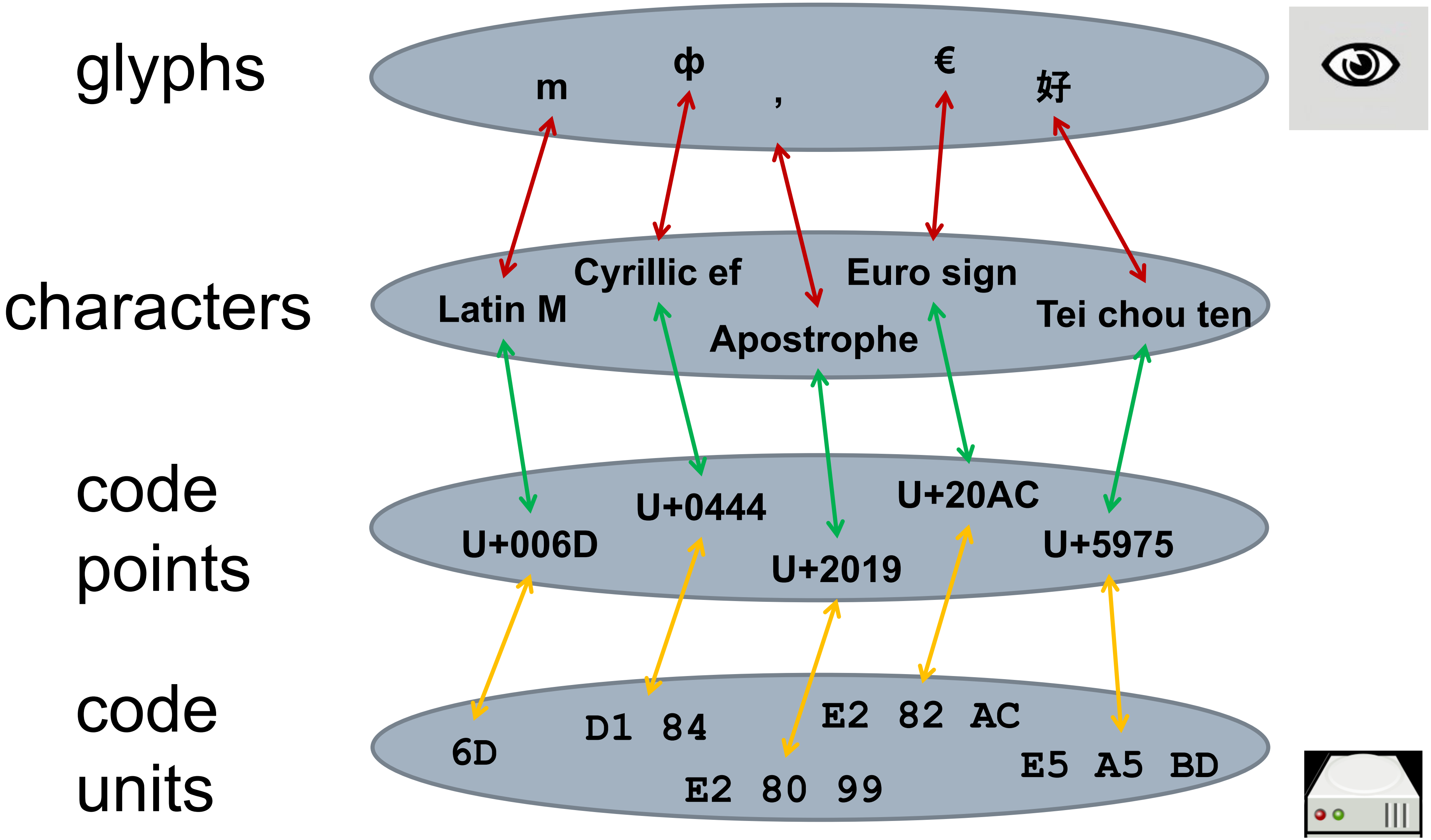




**Mayan numerals**

| | | |
|---|---|---|
| 1D2E0 | 𝋠 | MAYAN NUMERAL ZERO |
| 1D2E1 | 𝋡 | MAYAN NUMERAL ONE |
| 1D2E2 | 𝋢 | MAYAN NUMERAL TWO |
| 1D2E3 | 𝋣 | MAYAN NUMERAL THREE |
| 1D2E4 | 𝋤 | MAYAN NUMERAL FOUR |
| 1D2E5 | 𝋥 | MAYAN NUMERAL FIVE |
| 1D2E6 | 𝋦 | MAYAN NUMERAL SIX |
| 1D2E7 | 𝋧 | MAYAN NUMERAL SEVEN |
| 1D2E8 | 𝋨 | MAYAN NUMERAL EIGHT |
| 1D2E9 | 𝋩 | MAYAN NUMERAL NINE |
| 1D2EA | 𝋪 | MAYAN NUMERAL TEN |
| 1D2EB | 𝋫 | MAYAN NUMERAL ELEVEN |
| 1D2EC | 𝋬 | MAYAN NUMERAL TWELVE |
| 1D2ED | 𝋭 | MAYAN NUMERAL THIRTEEN |
| 1D2EE | 𝋮 | MAYAN NUMERAL FOURTEEN |
| 1D2EF | 𝋯 | MAYAN NUMERAL FIFTEEN |
| 1D2F0 | 𝋰 | MAYAN NUMERAL SIXTEEN |
| 1D2F1 | 𝋱 | MAYAN NUMERAL SEVENTEEN |
| 1D2F2 | 𝋲 | MAYAN NUMERAL EIGHTEEN |
| 1D2F3 | 𝋳 | MAYAN NUMERAL NINETEEN |

# Unicode: Mapping to Code Points



glyphs

m ф ’ € 好

characters

Latin M

Cyrillic ef

Apostrophe

Euro sign

Tei chou ten

code points

U+006D

U+0444

U+2019

U+20AC

U+5975

code units

6D

D1 84

E2 80 99

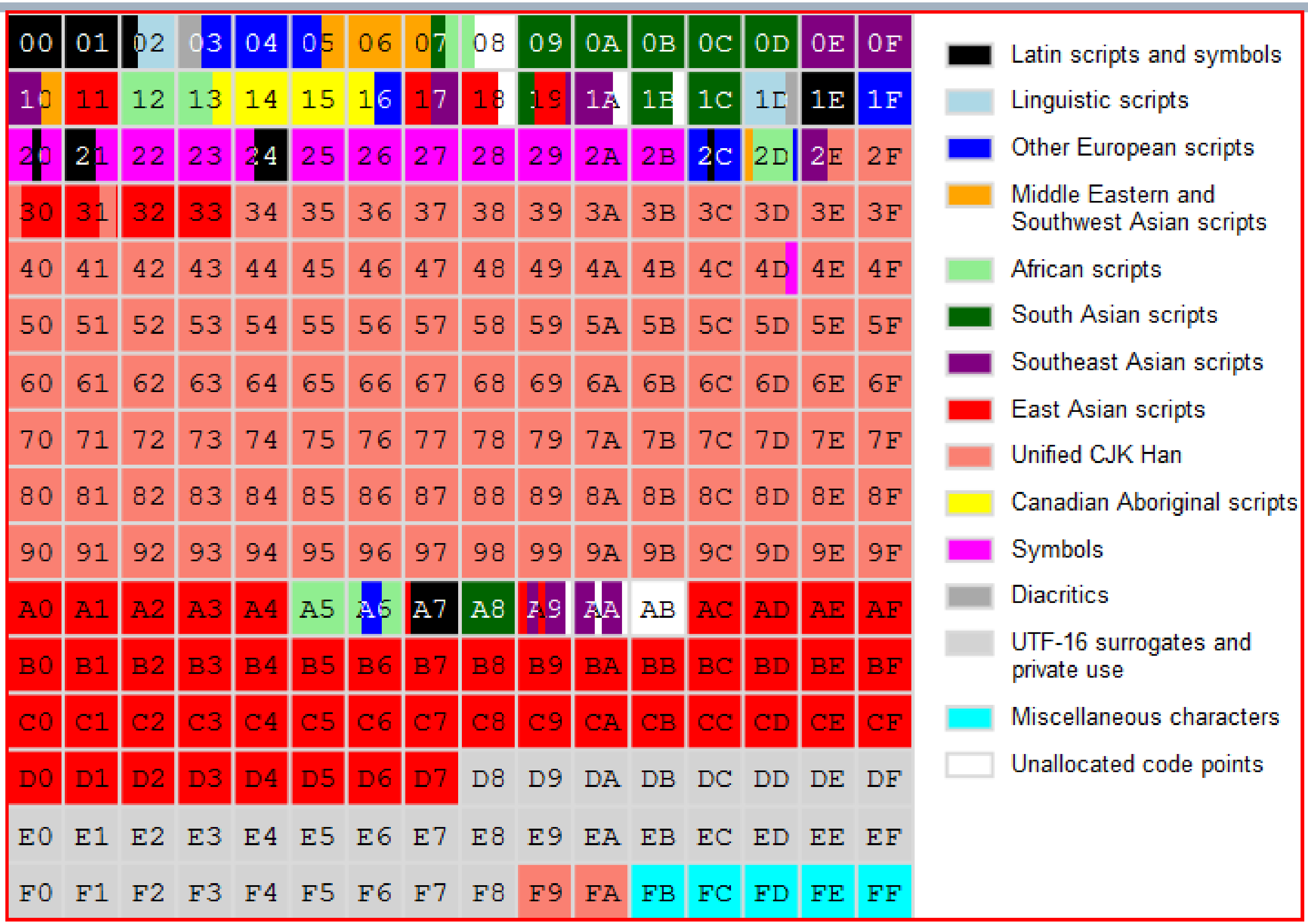
E2 82 AC

E5 A5 BD

# Organization

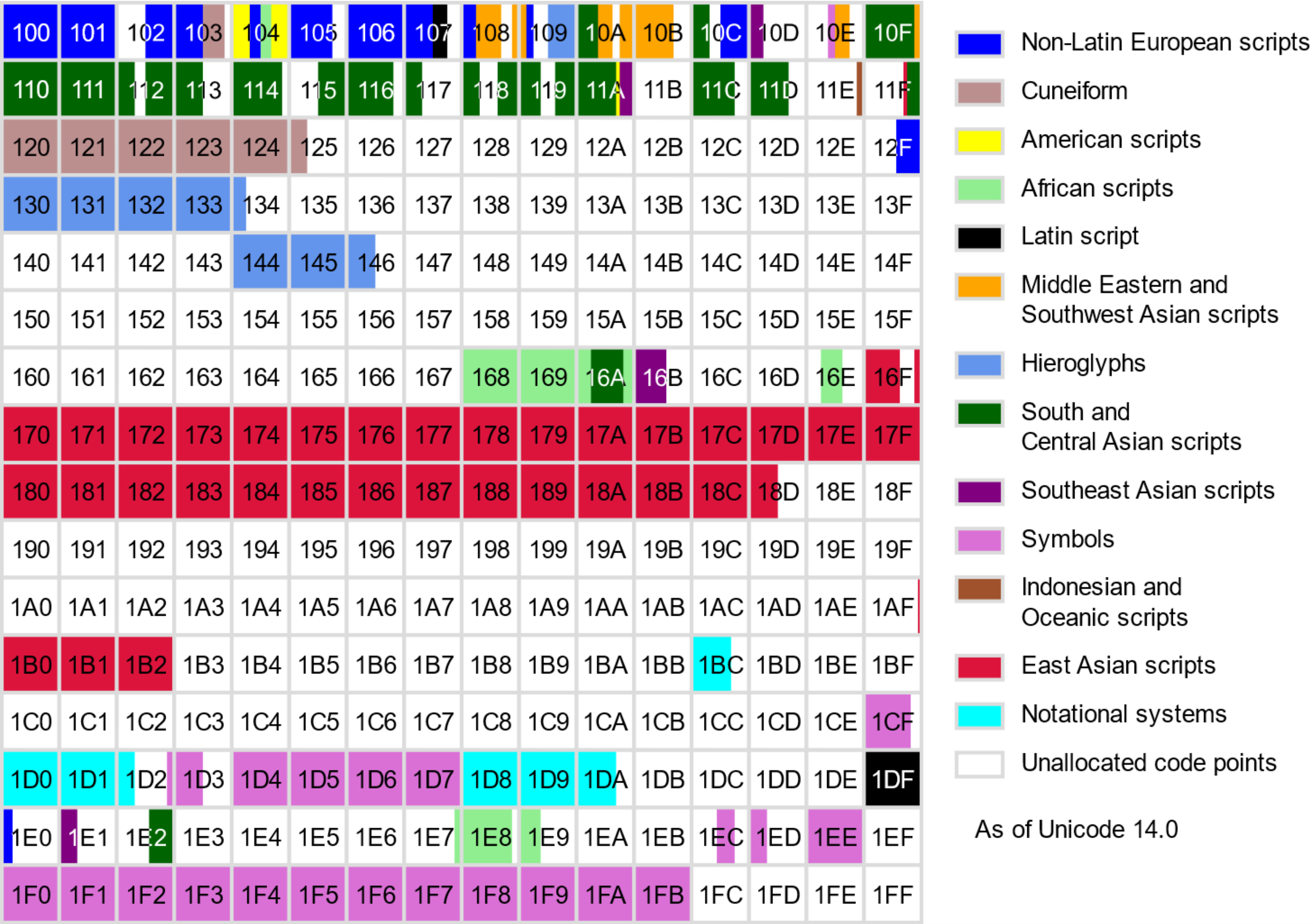
- Code points are grouped into categories
  - Basic Latin, Cyrillic, Arabic, Cherokee, Currency, Mathematical Operators, …
- Standard allows for 17 x $2^{16}$ code points
  - 0 to 1,114,111 (*i.e.*, > 1 million)
  - U+0000 to U+10FFFF
- Each group of $2^{16}$ called a *plane*
  - U+nnnnnn, same green ==> same plane
- Plane 0 called *basic multilingual plane* (BMP)
  - Has (practically) everything you could need
  - Convention: code points in BMP written U+nnnn (ie with leading 0's if needed)
  - Others code points written without leading 0's

# Basic Multilingual Plane



| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 0A | 0B | 0C | 0D | 0E | 0F |
| 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 1A | 1B | 1C | 1D | 1E | 1F |
| 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 2A | 2B | 2C | 2D | 2E | 2F |
| 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 3A | 3B | 3C | 3D | 3E | 3F |
| 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 4A | 4B | 4C | 4D | 4E | 4F |
| 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 5A | 5B | 5C | 5D | 5E | 5F |
| 60 | 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 | 6A | 6B | 6C | 6D | 6E | 6F |
| 70 | 71 | 72 | 73 | 74 | 75 | 76 | 77 | 78 | 79 | 7A | 7B | 7C | 7D | 7E | 7F |
| 80 | 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 | 8A | 8B | 8C | 8D | 8E | 8F |
| 90 | 91 | 92 | 93 | 94 | 95 | 96 | 97 | 98 | 99 | 9A | 9B | 9C | 9D | 9E | 9F |
| A0 | A1 | A2 | A3 | A4 | A5 | A6 | A7 | A8 | A9 | AA | AB | AC | AD | AE | AF |
| B0 | B1 | B2 | B3 | B4 | B5 | B6 | B7 | B8 | B9 | BA | BB | BC | BD | BE | BF |
| C0 | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | CA | CB | CC | CD | CE | CF |
| D0 | D1 | D2 | D3 | D4 | D5 | D6 | D7 | D8 | D9 | DA | DB | DC | DD | DE | DF |
| E0 | E1 | E2 | E3 | E4 | E5 | E6 | E7 | E8 | E9 | EA | EB | EC | ED | EE | EF |
| F0 | F1 | F2 | F3 | F4 | F5 | F6 | F7 | F8 | F9 | FA | FB | FC | FD | FE | FF |

# Supplemental Plane (plane 1)



| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 100 | 101 | 102 | 103 | 104 | 105 | 106 | 107 | 108 | 109 | 10A | 10B | 10C | 10D | 10E | 10F |
| 110 | 111 | 112 | 113 | 114 | 115 | 116 | 117 | 118 | 119 | 11A | 11B | 11C | 11D | 11E | 11F |
| 120 | 121 | 122 | 123 | 124 | 125 | 126 | 127 | 128 | 129 | 12A | 12B | 12C | 12D | 12E | 12F |
| 130 | 131 | 132 | 133 | 134 | 135 | 136 | 137 | 138 | 139 | 13A | 13B | 13C | 13D | 13E | 13F |
| 140 | 141 | 142 | 143 | 144 | 145 | 146 | 147 | 148 | 149 | 14A | 14B | 14C | 14D | 14E | 14F |
| 150 | 151 | 152 | 153 | 154 | 155 | 156 | 157 | 158 | 159 | 15A | 15B | 15C | 15D | 15E | 15F |
| 160 | 161 | 162 | 163 | 164 | 165 | 166 | 167 | 168 | 169 | 16A | 16B | 16C | 16D | 16E | 16F |
| 170 | 171 | 172 | 173 | 174 | 175 | 176 | 177 | 178 | 179 | 17A | 17B | 17C | 17D | 17E | 17F |
| 180 | 181 | 182 | 183 | 184 | 185 | 186 | 187 | 188 | 189 | 18A | 18B | 18C | 18D | 18E | 18F |
| 190 | 191 | 192 | 193 | 194 | 195 | 196 | 197 | 198 | 199 | 19A | 19B | 19C | 19D | 19E | 19F |
| 1A0 | 1A1 | 1A2 | 1A3 | 1A4 | 1A5 | 1A6 | 1A7 | 1A8 | 1A9 | 1AA | 1AB | 1AC | 1AD | 1AE | 1AF |
| 1B0 | 1B1 | 1B2 | 1B3 | 1B4 | 1B5 | 1B6 | 1B7 | 1B8 | 1B9 | 1BA | 1BB | 1BC | 1BD | 1BE | 1BF |
| 1C0 | 1C1 | 1C2 | 1C3 | 1C4 | 1C5 | 1C6 | 1C7 | 1C8 | 1C9 | 1CA | 1CB | 1CC | 1CD | 1CE | 1CF |
| 1D0 | 1D1 | 1D2 | 1D3 | 1D4 | 1D5 | 1D6 | 1D7 | 1D8 | 1D9 | 1DA | 1DB | 1DC | 1DD | 1DE | 1DF |
| 1E0 | 1E1 | 1E2 | 1E3 | 1E4 | 1E5 | 1E6 | 1E7 | 1E8 | 1E9 | 1EA | 1EB | 1EC | 1ED | 1EE | 1EF |
| 1F0 | 1F1 | 1F2 | 1F3 | 1F4 | 1F5 | 1F6 | 1F7 | 1F8 | 1F9 | 1FA | 1FB | 1FC | 1FD | 1FE | 1FF |

🟦 Non-Latin European scripts

🟫 Cuneiform

🟨 American scripts

🟩 African scripts

⬛ Latin script

🟧 Middle Eastern and Southwest Asian scripts

🟦 Hieroglyphs

🟩 South and Central Asian scripts

🟪 Southeast Asian scripts

🟪 Symbols

🟫 Indonesian and Oceanic scripts

🟥 East Asian scripts

🟦 Notational systems

⬜ Unallocated code points

As of Unicode 14.0

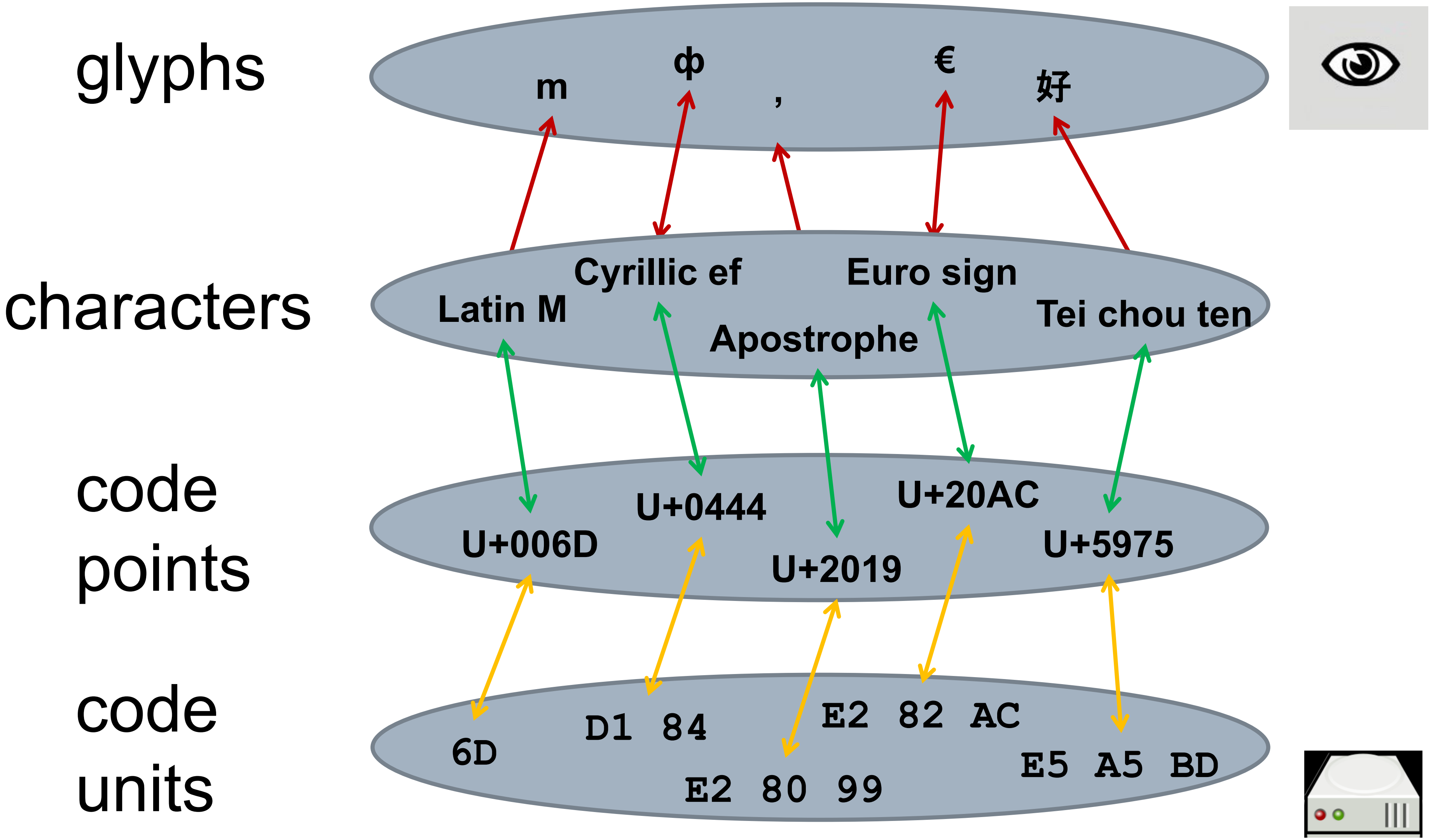
# UTF-8

- Encoding of code point (integer) in a sequence of bytes (octets)
  - Standard: all caps, with hyphen (UTF-8)
- Variable length
  - Some code points require 1 octet
  - Others require 2, 3, or 4
- Consequence: Can not infer number of characters from size of file!
- No endian-ness: just a *sequence* of octets

```
D0 BF D1 80 D0 B8 D0 B2 D0 B5 D1 82...
```

- Other encodings exist!
  - Eg UTF-16 use 16 bits (more general term: *code unit*)

# UTF-8: Code Points & Octets



glyphs

m ф ’ € 好

characters

Latin M
Cyrillic ef
Apostrophe
Euro sign
Tei chou ten

code points

U+006D
U+0444
U+2019
U+20AC
U+5975

code units

6D
D1 84
E2 80 99
E2 82 AC
E5 A5 BD

# UTF-8 Encoding Recipe

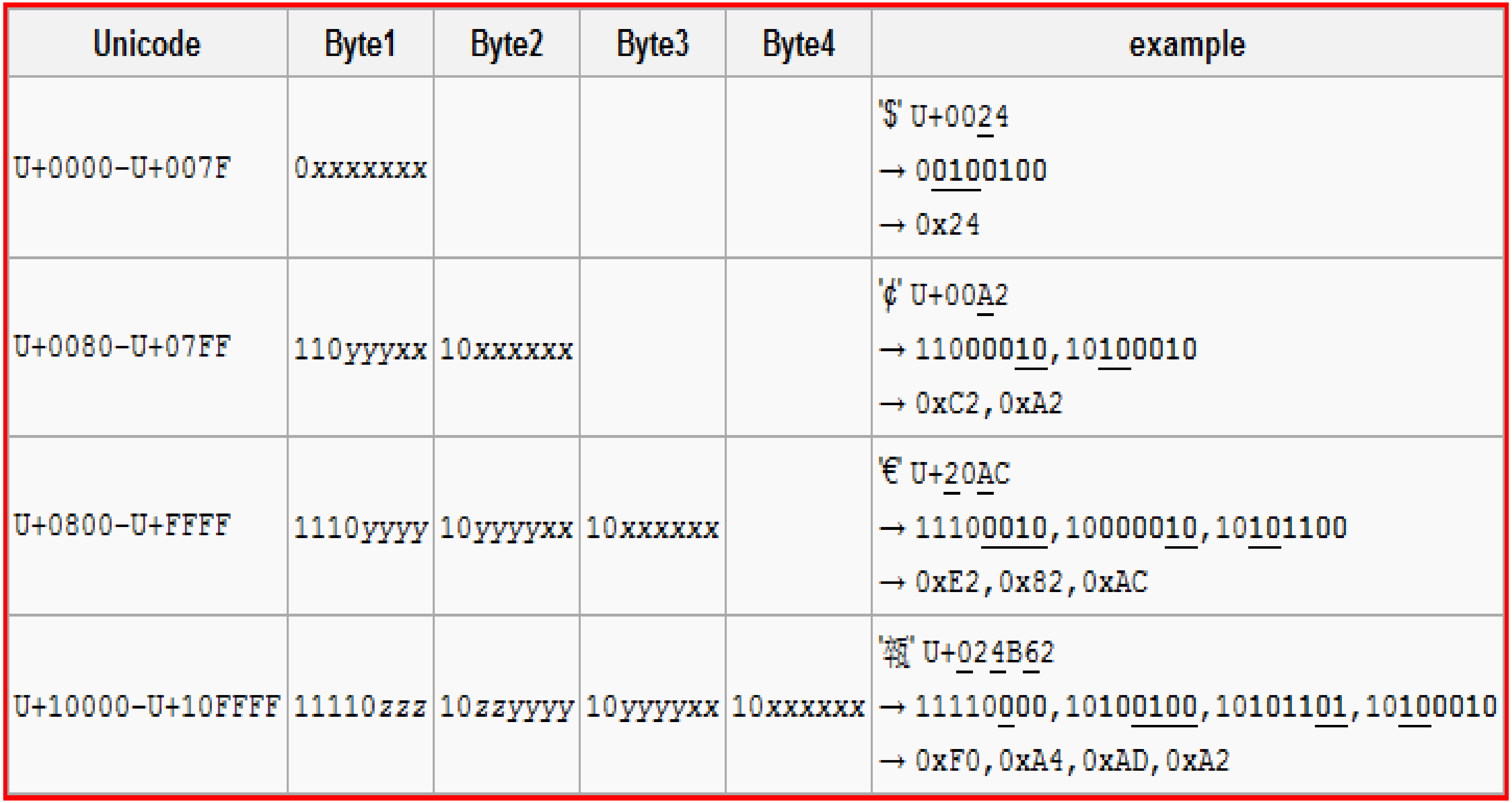
- 1-byte encodings
  - First bit is 0
  - Example: **0**110 1101 (encodes U+006D)
- 2-byte encodings
  - First byte starts with **110**…
  - Second byte starts with **10**…
    - Example: **110**1 0000   **10**11 1111
    - Payload: 110**1 0000**   10**11 1111**  
      = 100   0011  1111  
      = 0x043F
    - Code point: U+043F  
      *i.e.* п, Cyrillic small letter pe

# UTF-8 Encoding Recipe

- Generalization: An encoding of length k:
  - First byte starts with k **1**'s, then **0**
    - Example **1110** 0110 ==> first byte of a 3-byte encoding
  - Subsequent k-1 bytes each start with **10**
  - Remaining bits are payload
- Example: E2 82 AC

  11100010 10000010 10101100
  - Payload: 0x20AC (*i.e.*, U+20AC, €)
- Consequence: Stream is *self-synchronizing*
  - A dropped byte affects only that character

# UTF-8 Encoding Summary



| Unicode | Byte1 | Byte2 | Byte3 | Byte4 | example |
|---|---|---|---|---|---|
| U+0000-U+007F | 0xxxxxxx | | | | '$' U+0024<br>→ 00100100<br>→ 0x24 |
| U+0080-U+07FF | 110yyyxx | 10xxxxxx | | | '¢' U+00A2<br>→ 11000010,10100010<br>→ 0xC2,0xA2 |
| U+0800-U+FFFF | 1110yyyy | 10yyyyxx | 10xxxxxx | | '€' U+20AC<br>→ 11100010,10000010,10101100<br>→ 0xE2,0x82,0xAC |
| U+10000-U+10FFFF | 11110zzz | 10zzyyyy | 10yyyyxx | 10xxxxxx | '𤭢' U+024B62<br>→ 11110000,10100100,10101101,10100010<br>→ 0xF0,0xA4,0xAD,0xA2 |

(from wikipedia)

# Your Turn

- For the following UTF-8 encoding, what is the corresponding code point(s)?
  - F0 A4 AD A2
- For the following Unicode code point, what is its UTF-8 encoding?
  - U+20AC

# Security Issue

- Not all octet sequences are encodings
  - "overlong" encodings are illegal
  - example: C0 AF  
    = **110**0 00**00** **10**10 1111  
    = U+002F (should be encoded 2F)
- Classic security bug (IIS 2001)
  - Should reject URL requests with "../.."
    - Scanned for 2E 2E 2F 2E 2E (in encoding)
  - Accepted "..%c0%af.." (doesn't contain x2F)
    - 2E 2E C0 AF 2E 2E
  - *After* accepting, server *then* decoded
    - 2E 2E C0 AF 2E 2E decoded into "../.."
- Moral: Strings are sequences of "code units"
  - But we think (and see) code points

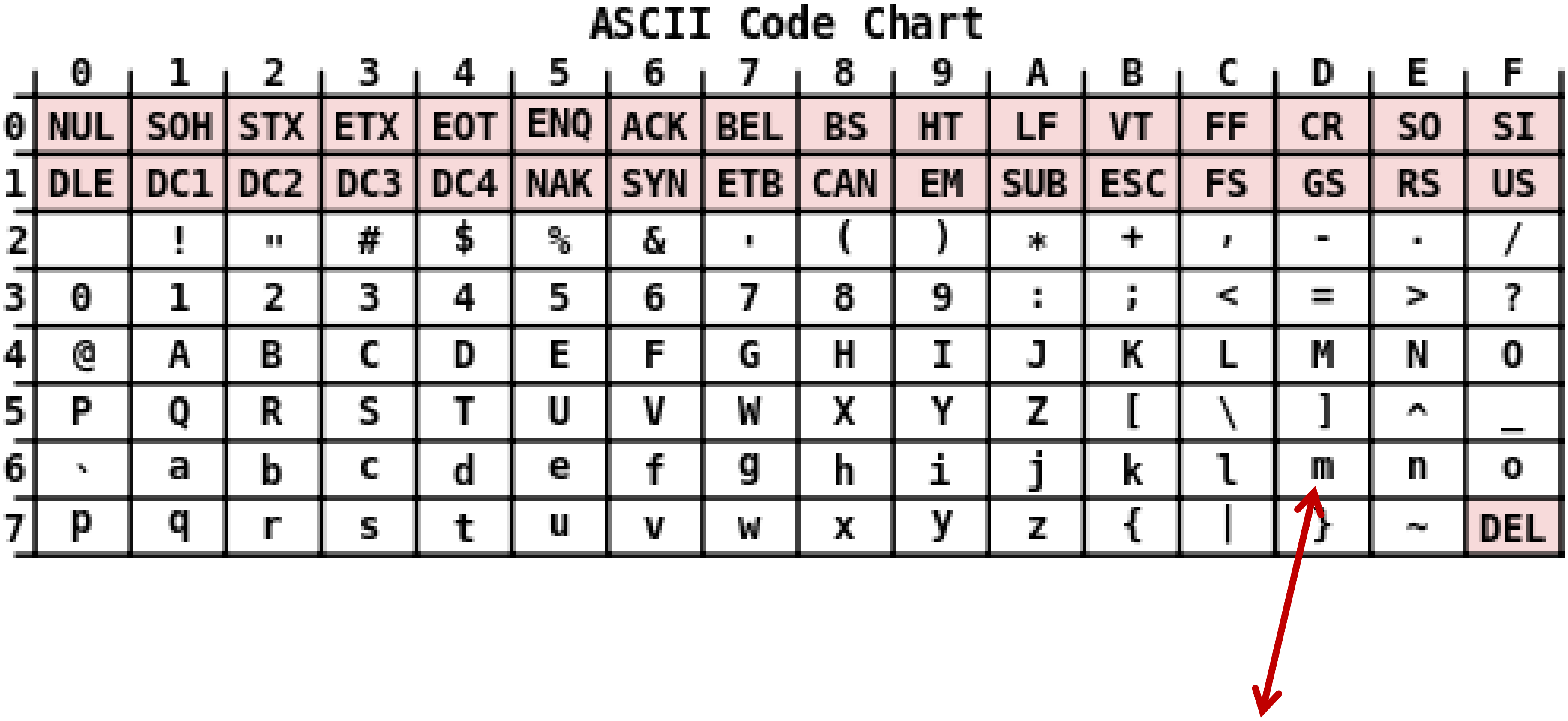
# Recall: URL encoding

- Concrete invariant (convention)
  - No space, ;, :, & in representation
  - To represent these characters, use %hh instead (hh is ASCII code in hex)
    - %20 for space
  - Q: What about % in abstract value?
- Recall: *correspondence relation*

# Other (Older) Encodings

- In the beginning…
- Character sets were small
  - ASCII: only 128 characters (ie $2^7$)
  - 1 byte/character, leading bit always 0
- Globalization means more characters…
  - But 1 byte/character seems fundamental
- Solutions:
  - Use that leading bit!
    - Text data now looks just like binary data
  - Use more than 1 encoding!
    - Must specify data + encoding used

# ASCII: 128 Codes

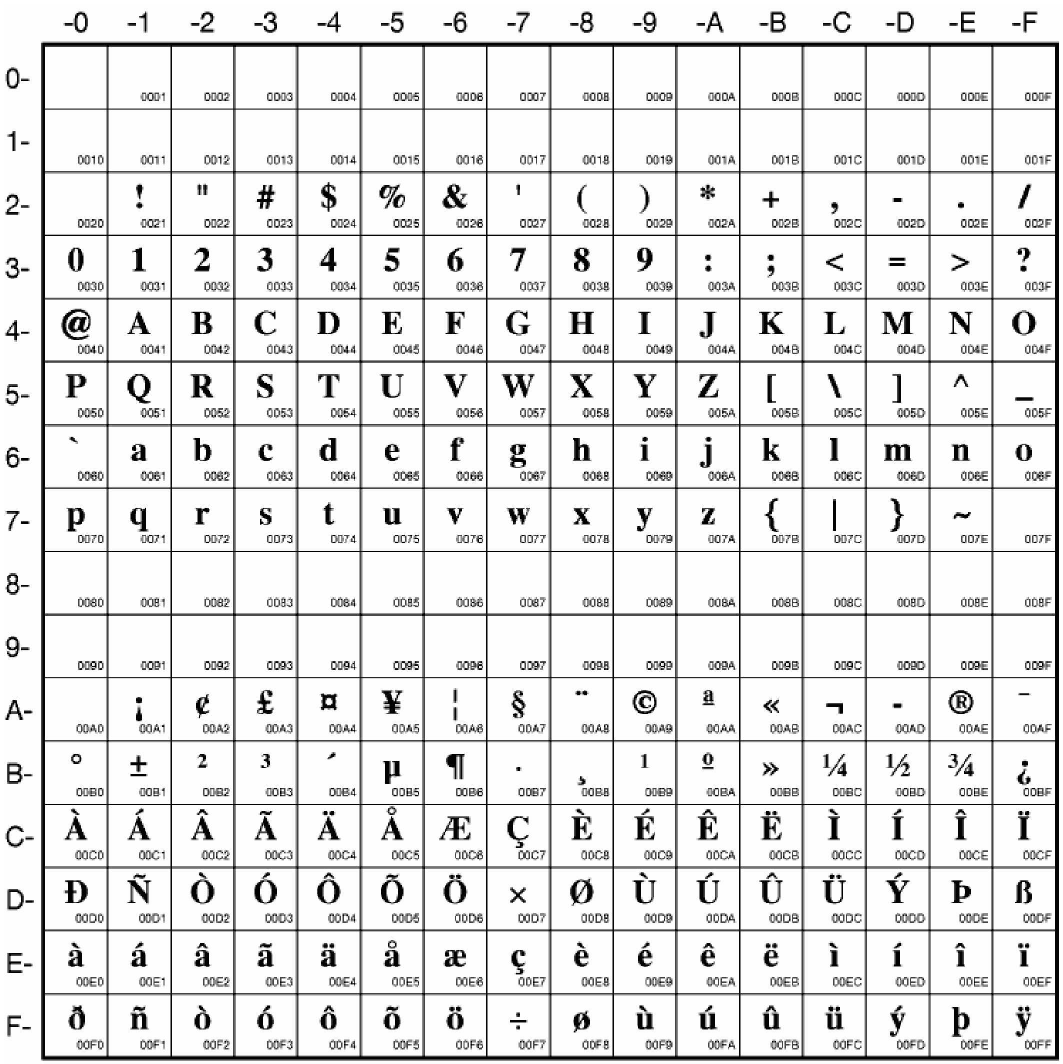


ASCII Code Chart

| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | A | B | C | D | E | F |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | NUL | SOH | STX | ETX | EOT | ENQ | ACK | BEL | BS | HT | LF | VT | FF | CR | SO | SI |
| 1 | DLE | DC1 | DC2 | DC3 | DC4 | NAK | SYN | ETB | CAN | EM | SUB | ESC | FS | GS | RS | US |
| 2 | | ! | " | # | $ | % | & | ' | ( | ) | * | + | , | - | . | / |
| 3 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | : | ; | < | = | > | ? |
| 4 | @ | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O |
| 5 | P | Q | R | S | T | U | V | W | X | Y | Z | [ | \ | ] | ^ | _ |
| 6 | ` | a | b | c | d | e | f | g | h | i | j | k | l | m | n | o |
| 7 | p | q | r | s | t | u | v | w | x | y | z | { | \| | } | ~ | DEL |

6D = Latin small m

# ISO-8859 family (eg -1 Latin)



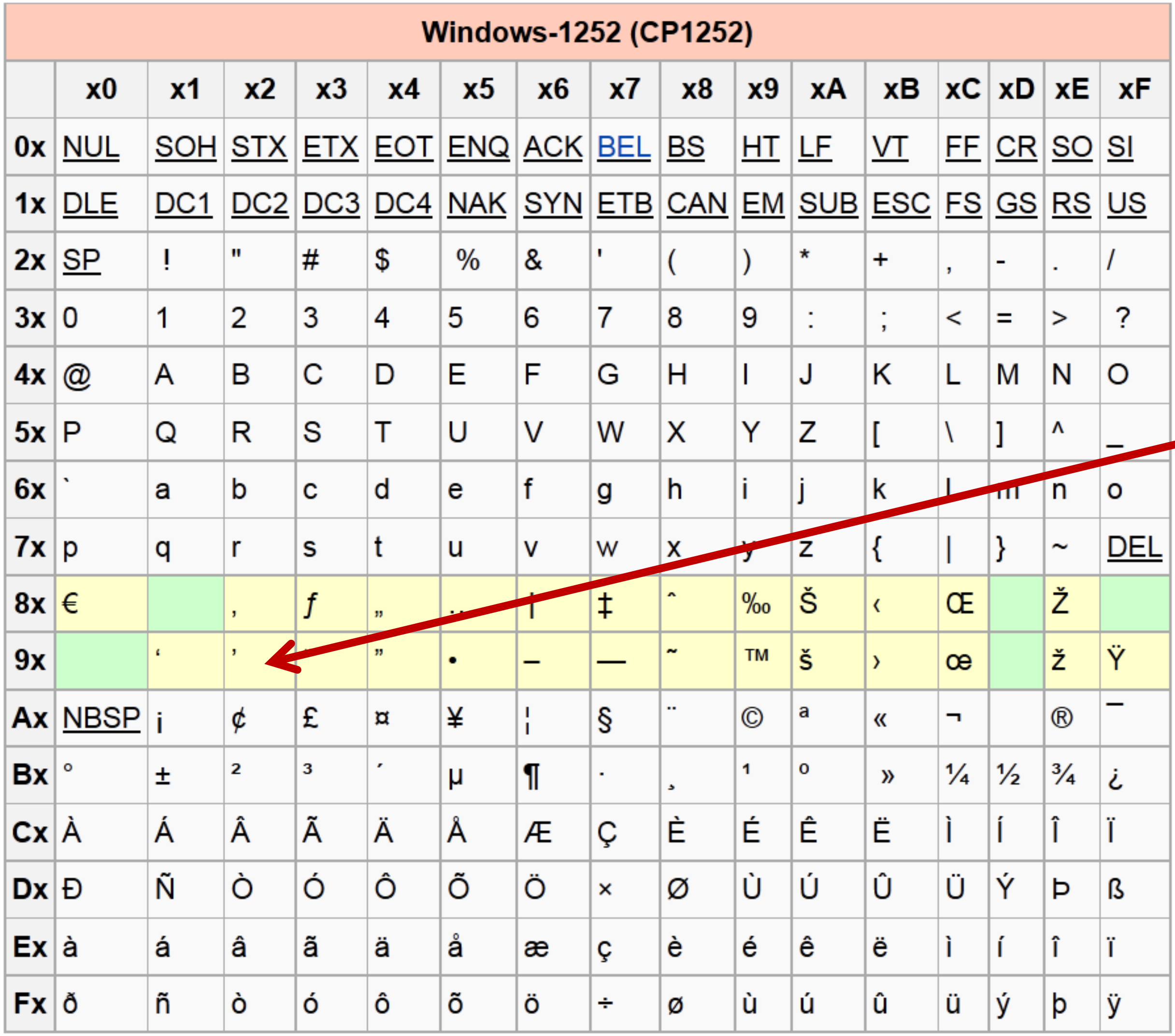
| | -0 | -1 | -2 | -3 | -4 | -5 | -6 | -7 | -8 | -9 | -A | -B | -C | -D | -E | -F |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0- | | 0001 | 0002 | 0003 | 0004 | 0005 | 0006 | 0007 | 0008 | 0009 | 000A | 000B | 000C | 000D | 000E | 000F |
| 1- | 0010 | 0011 | 0012 | 0013 | 0014 | 0015 | 0016 | 0017 | 0018 | 0019 | 001A | 001B | 001C | 001D | 001E | 001F |
| 2- | 0020 | ! 0021 | " 0022 | # 0023 | $ 0024 | % 0025 | & 0026 | ' 0027 | ( 0028 | ) 0029 | * 002A | + 002B | , 002C | - 002D | . 002E | / 002F |
| 3- | 0 0030 | 1 0031 | 2 0032 | 3 0033 | 4 0034 | 5 0035 | 6 0036 | 7 0037 | 8 0038 | 9 0039 | : 003A | ; 003B | < 003C | = 003D | > 003E | ? 003F |
| 4- | @ 0040 | A 0041 | B 0042 | C 0043 | D 0044 | E 0045 | F 0046 | G 0047 | H 0048 | I 0049 | J 004A | K 004B | L 004C | M 004D | N 004E | O 004F |
| 5- | P 0050 | Q 0051 | R 0052 | S 0053 | T 0054 | U 0055 | V 0056 | W 0057 | X 0058 | Y 0059 | Z 005A | [ 005B | \ 005C | ] 005D | ^ 005E | _ 005F |
| 6- | ` 0060 | a 0061 | b 0062 | c 0063 | d 0064 | e 0065 | f 0066 | g 0067 | h 0068 | i 0069 | j 006A | k 006B | l 006C | m 006D | n 006E | o 006F |
| 7- | p 0070 | q 0071 | r 0072 | s 0073 | t 0074 | u 0075 | v 0076 | w 0077 | x 0078 | y 0079 | z 007A | { 007B | \| 007C | } 007D | ~ 007E | 007F |
| 8- | 0080 | 0081 | 0082 | 0083 | 0084 | 0085 | 0086 | 0087 | 0088 | 0089 | 008A | 008B | 008C | 008D | 008E | 008F |
| 9- | 0090 | 0091 | 0092 | 0093 | 0094 | 0095 | 0096 | 0097 | 0098 | 0099 | 009A | 009B | 009C | 009D | 009E | 009F |
| A- | 00A0 | ¡ 00A1 | ¢ 00A2 | £ 00A3 | ¤ 00A4 | ¥ 00A5 | ¦ 00A6 | § 00A7 | ¨ 00A8 | © 00A9 | ª 00AA | « 00AB | ¬ 00AC | - 00AD | ® 00AE | ¯ 00AF |
| B- | ° 00B0 | ± 00B1 | ² 00B2 | ³ 00B3 | ´ 00B4 | µ 00B5 | ¶ 00B6 | · 00B7 | ¸ 00B8 | ¹ 00B9 | º 00BA | » 00BB | ¼ 00BC | ½ 00BD | ¾ 00BE | ¿ 00BF |
| C- | À 00C0 | Á 00C1 | Â 00C2 | Ã 00C3 | Ä 00C4 | Å 00C5 | Æ 00C6 | Ç 00C7 | È 00C8 | É 00C9 | Ê 00CA | Ë 00CB | Ì 00CC | Í 00CD | Î 00CE | Ï 00CF |
| D- | Ð 00D0 | Ñ 00D1 | Ò 00D2 | Ó 00D3 | Ô 00D4 | Õ 00D5 | Ö 00D6 | × 00D7 | Ø 00D8 | Ù 00D9 | Ú 00DA | Û 00DB | Ü 00DC | Ý 00DD | Þ 00DE | ß 00DF |
| E- | à 00E0 | á 00E1 | â 00E2 | ã 00E3 | ä 00E4 | å 00E5 | æ 00E6 | ç 00E7 | è 00E8 | é 00E9 | ê 00EA | ë 00EB | ì 00EC | í 00ED | î 00EE | ï 00EF |
| F- | ð 00F0 | ñ 00F1 | ò 00F2 | ó 00F3 | ô 00F4 | õ 00F5 | ö 00F6 | ÷ 00F7 | ø 00F8 | ù 00F9 | ú 00FA | û 00FB | ü 00FC | ý 00FD | þ 00FE | ÿ 00FF |

0-7F match ASCII

reserved
(control characters)

A0-FF differ, eg:
-1 "Western"
-2 "East European"
-9 "Turkish"

# Windows Family (eg 1252 Latin)

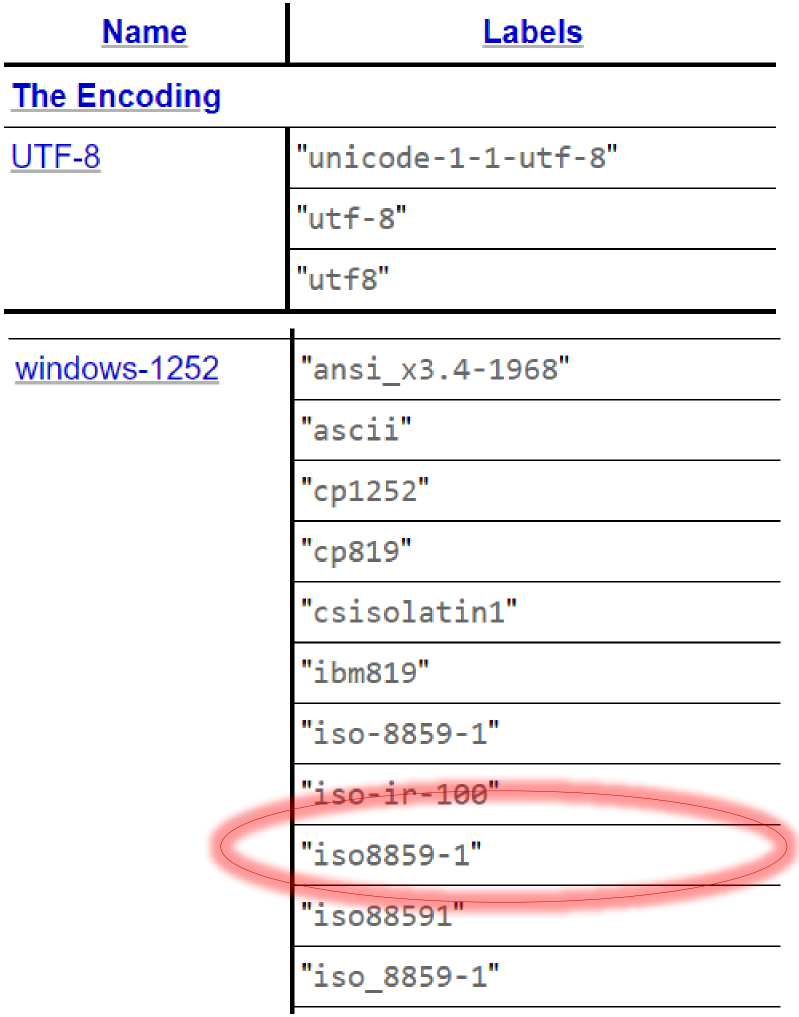


Windows-1252 (CP1252)

| | x0 | x1 | x2 | x3 | x4 | x5 | x6 | x7 | x8 | x9 | xA | xB | xC | xD | xE | xF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0x | NUL | SOH | STX | ETX | EOT | ENQ | ACK | BEL | BS | HT | LF | VT | FF | CR | SO | SI |
| 1x | DLE | DC1 | DC2 | DC3 | DC4 | NAK | SYN | ETB | CAN | EM | SUB | ESC | FS | GS | RS | US |
| 2x | SP | ! | " | # | $ | % | & | ' | ( | ) | * | + | , | - | . | / |
| 3x | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | : | ; | < | = | > | ? |
| 4x | @ | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O |
| 5x | P | Q | R | S | T | U | V | W | X | Y | Z | [ | \ | ] | ^ | _ |
| 6x | ` | a | b | c | d | e | f | g | h | i | j | k | l | m | n | o |
| 7x | p | q | r | s | t | u | v | w | x | y | z | { | \| | } | ~ | DEL |
| 8x | € | | ‚ | ƒ | „ | … | † | ‡ | ˆ | ‰ | Š | ‹ | Œ | | Ž | |
| 9x | | ‘ | ’ | “ | ” | • | – | — | ˜ | ™ | š | › | œ | | ž | Ÿ |
| Ax | NBSP | ¡ | ¢ | £ | ¤ | ¥ | ¦ | § | ¨ | © | ª | « | ¬ | | ® | ¯ |
| Bx | ° | ± | ² | ³ | ´ | µ | ¶ | · | ¸ | ¹ | º | » | ¼ | ½ | ¾ | ¿ |
| Cx | À | Á | Â | Ã | Ä | Å | Æ | Ç | È | É | Ê | Ë | Ì | Í | Î | Ï |
| Dx | Ð | Ñ | Ò | Ó | Ô | Õ | Ö | × | Ø | Ù | Ú | Û | Ü | Ý | Þ | ß |
| Ex | à | á | â | ã | ä | å | æ | ç | è | é | ê | ë | ì | í | î | ï |
| Fx | ð | ñ | ò | ó | ô | õ | ö | ÷ | ø | ù | ú | û | ü | ý | þ | ÿ |

92 = apostrophe

# HTML 5 Standard



| Name | Labels |
|---|---|
| The Encoding | |
| UTF-8 | "unicode-1-1-utf-8" |
| | "utf-8" |
| | "utf8" |
| windows-1252 | "ansi_x3.4-1968" |
| | "ascii" |
| | "cp1252" |
| | "cp819" |
| | "csisolatin1" |
| | "ibm819" |
| | "iso-8859-1" |
| | "iso-ir-100" |
| | "iso8859-1" |
| | "iso88591" |
| | "iso_8859-1" |

# Early Unicode and UTF-16

- Unicode started as $2^{16}$ code points
  - The BMP of modern Unicode
  - Bottom 256 code points match ISO-8859-1
- Simple 1:1 encoding (UTF-16)
  - Code point <--> 16-bit code unit
  - Simple, but leads to bloat of ASCII text
- Later added code points *outside* of BMP
  - A pair of words (surrogate pairs) carry 20-bit payload split, 10 bits in each word
  - First: **1101 10**xx xxxx xxxx (xD800-DBFF)
  - Second: **1101 11**yy yyyy yyyy (xDC00-DFFF)
- Consequence: U+D800 to U+DFFF became reserved code points in Unicode
  - And now we are stuck with this legacy, even for UTF-8

# Demo

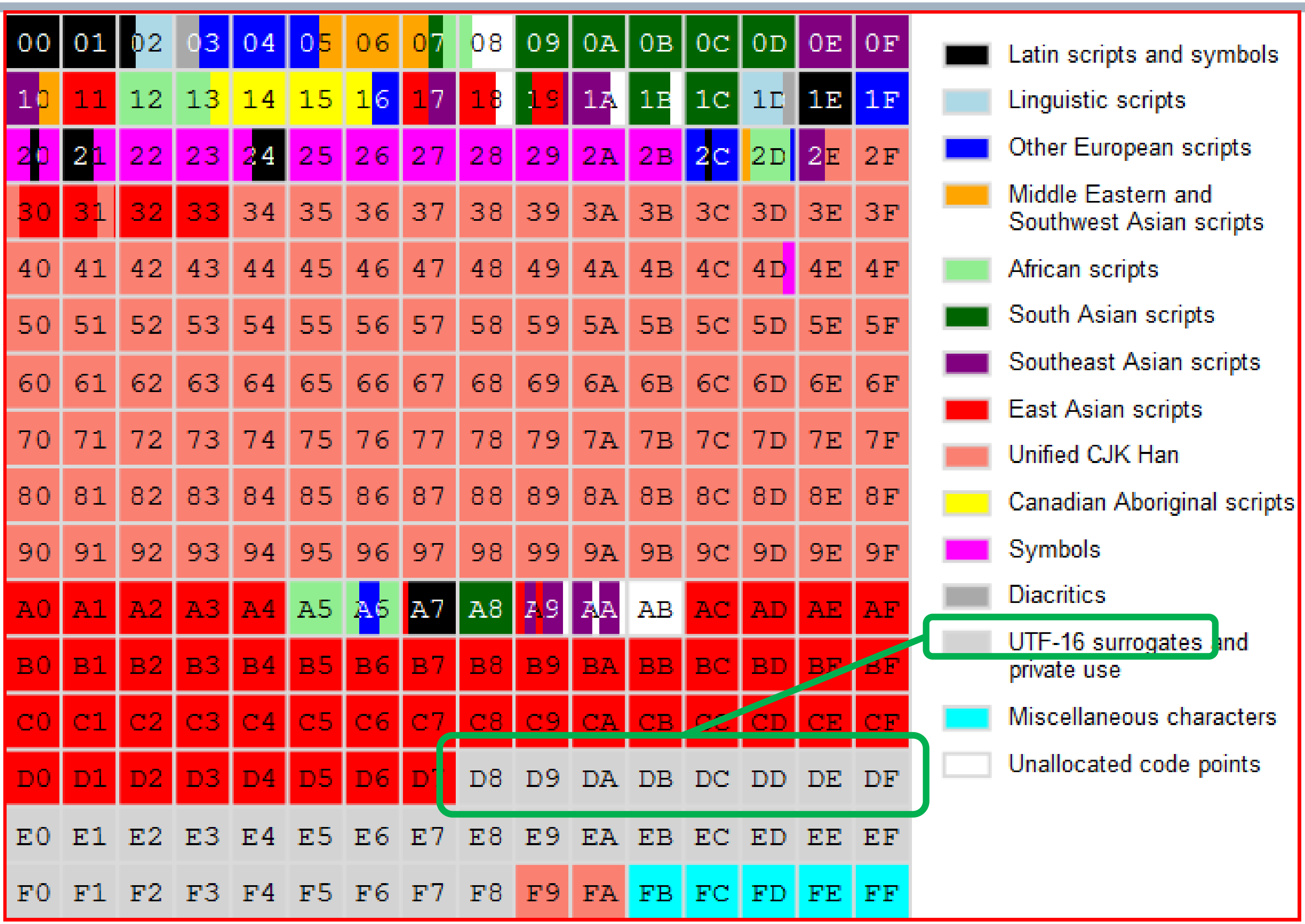
□ JavaScript and UTF-16

```
let x = "\u{1f916}"    // robot face
x.codePointAt(0).toString(16)
x.length         // number of code units
x.charCodeAt(0).toString(16);
x.charAt(0);     // char from 1 code unit
```

□ Ruby and string encodings

```
x = "\u{1f916}"
x.length
x.bytes.map { |b| b.to_s(2) }
x.encoding
x.encode! Encoding::UTF_16
x.bytes.map { |b| b.to_s(16) }
```

# Basic Multilingual Plane



| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 0A | 0B | 0C | 0D | 0E | 0F |
| 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 1A | 1B | 1C | 1D | 1E | 1F |
| 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 2A | 2B | 2C | 2D | 2E | 2F |
| 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 3A | 3B | 3C | 3D | 3E | 3F |
| 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 4A | 4B | 4C | 4D | 4E | 4F |
| 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 5A | 5B | 5C | 5D | 5E | 5F |
| 60 | 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 | 6A | 6B | 6C | 6D | 6E | 6F |
| 70 | 71 | 72 | 73 | 74 | 75 | 76 | 77 | 78 | 79 | 7A | 7B | 7C | 7D | 7E | 7F |
| 80 | 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 | 8A | 8B | 8C | 8D | 8E | 8F |
| 90 | 91 | 92 | 93 | 94 | 95 | 96 | 97 | 98 | 99 | 9A | 9B | 9C | 9D | 9E | 9F |
| A0 | A1 | A2 | A3 | A4 | A5 | A6 | A7 | A8 | A9 | AA | AB | AC | AD | AE | AF |
| B0 | B1 | B2 | B3 | B4 | B5 | B6 | B7 | B8 | B9 | BA | BB | BC | BD | BE | BF |
| C0 | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | CA | CB | CC | CD | CE | CF |
| D0 | D1 | D2 | D3 | D4 | D5 | D6 | D7 | D8 | D9 | DA | DB | DC | DD | DE | DF |
| E0 | E1 | E2 | E3 | E4 | E5 | E6 | E7 | E8 | E9 | EA | EB | EC | ED | EE | EF |
| F0 | F1 | F2 | F3 | F4 | F5 | F6 | F7 | F8 | F9 | FA | FB | FC | FD | FE | FF |

- ■ Latin scripts and symbols
- ■ Linguistic scripts
- ■ Other European scripts
- ■ Middle Eastern and Southwest Asian scripts
- ■ African scripts
- ■ South Asian scripts
- ■ Southeast Asian scripts
- ■ East Asian scripts
- ■ Unified CJK Han
- ■ Canadian Aboriginal scripts
- ■ Symbols
- ■ Diacritics
- ■ UTF-16 surrogates and private use
- ■ Miscellaneous characters
- □ Unallocated code points

# UTF-16 and Endianness

- A multi-byte representation must distinguish between big & little endian
  - Example: 00 25 00 25 00 25
  - "%%%" if LE, "— — —" if BE
- One solution: Specify encoding in name
  - UTF-16BE or UTF-16LE
- Another solution: require *byte order mark* (BOM) at the start of the file
  - U+FEFF (ZERO WIDTH NO BREAK SPACE)
  - There is *no* U+FFFE code point
  - So FE FF ➔ BigE, while FF FE ➔ LittleE
  - Not considered part of the text

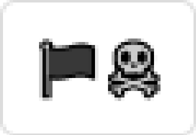
# BOM and UTF-8

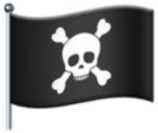
- Should we add a BOM to the start of UTF-8 files too?
  - UTF-8 encoding of U+FEFF is EF BB BF
- Advantages:
  - Forms magic-number for UTF-8 encoding
- Disadvantages:
  - Not backwards-compatible to ASCII
  - Existing programs may no longer work
  - *E.g.*, In Unix, shebang (#!, *i.e.* 23 21) at *start* of file is significant: file is a script

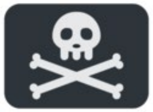
    ```
    #! /bin/bash
    ```

# ZWJ: Zero Width Joiner

- Using U+FEFF as ZWNBSP deprecated
  - Reserved for BOM uses (at start of file)
- Alternative: U+200D (“zwidge”)
- Joined characters may be rendered as a single glyph
  - Co-opted for use with emojis
- Example: (1 “character” in Twitter)
  - U+1F3F4 U+200D U+2620
  - WAVING BLACK FLAG, ZWJ, SKULL AND CROSSBONES







# To Ponder

- What is a “text” file? (vs “binary”)
  - Given a file, how can you tell which it is?
- A JavaScript program reads in a 5MB file of English prose into a string. How much memory does the string need?
- How many characters does **s** contain?

```
let s = . . . // JavaScript
console.assert (s.length() == 7) // true
```

- Which is better: UTF-8 or UTF-16?
- What’s so scary about:

```
..%c0%af..
```

# Summary

- Text vs binary
  - In pre-historic times: most significant bit
  - Now: data is data
- Unicode code points
  - Integers U+0000..U+10FFFF
  - BMP: Basic Multilingual Plane
- UTF-8
  - A variable-length, self-synchronizing encoding of unicode code points
  - Backwards compatible with ISO 8859-1, and hence with ASCII too