

# Character Data

Huge number of character representations (encodings) exist  
you need know only two:

- ASCII (ISO 646)
  - single byte values, only low 7-bit used, top bit always 0
  - can encode roman alphabet a-zA-Z, digits 0-9 , punctuation, control chars
  - complete alphabet for English, Bahasa
  - no diacritics, e.g: ç , so missing a little of alphabet for other latin languages, e.g.: German, French, Spanish, Italian, Swedish, Tagalog, Swahili
  - characters for most of world's languages completely missing
- UTF-8 (Unicode)
  - contains all ASCII (single-byte) values
  - also has 2-4 byte values, top bit always 1 for bytes of multi-byte values
  - contains symbols for essentially all human languages plus other symbols, e.g.:

✓ ∑ ∇ ∃



# ASCII Character Encoding

- Uses values in the range 0x00 to 0x7F (0..127)
- Characters partitioned into sequential groups
  - control characters (0..31) ... e.g. `'\n'`
  - punctuation chars (32..47,91..96,123..126)
  - digits (48..57) ... `'0'..'9'`
  - upper case alphabetic (65..90) ... `'A'..'Z'`
  - lower case alphabetic (97..122) ... `'a'..'z'`
- Sequential nature of groups allow ordination e.g.  
`'3' - '0' == 3`   `'J' - 'A' == 10`
- See **man 7 ascii**

- Widely-used standard for expressing “writing systems”
  - not all writing systems use a small set of discrete symbols
- Basically, a 32-bit representation of a wide range of symbols
  - around 140K symbols, covering 140 different languages
- Using 32-bits for every symbol would be too expensive
  - e.g. standard roman alphabet + punctuation needs only 7-bits
  - Several Unicode encodings have been developed
  - UTF-8 most widely used encoding, dominates web-use
  - designed by Ken Thompson on napkin in New Jersey diner

# UTF-8 Encoding

<i>#bytes</i>	<i>#bits</i>	<i>Byte 1</i>	<i>Byte 2</i>	<i>Byte 3</i>	<i>Byte 4</i>
1	7	0xxxxxxx	-	-	-
2	11	110xxxxx	10xxxxxx	-	-
3	16	1110xxxx	10xxxxxx	10xxxxxx	-
4	21	11110xxx	10xxxxxx	10xxxxxx	10xxxxxx

- The 127 1-byte codes are compatible with ASCII
- The 2048 2-byte codes include most Latin-script alphabets
- The 65536 3-byte codes include most Asian languages
- The 2097152 4-byte codes include symbols and emojis and ...

<i>ch</i>	<i>code-point</i>	<i>unicode binary</i>	<i>UTF-8 encoding</i>
\$	U+0024	<b>0100100</b>	<b>00100100</b>
¢	U+00A2	<b>00010100010</b>	<b>11000010 10100010</b>
€	U+20AC	<b>00100000010101100</b>	<b>11100010 10000010 10101100</b>

# Printing UTF-8 in a C program

```
printf("The unicode code point U+1F600 encodes in UTF-8\n");  
printf("as 4 bytes: 0xF0 0x9F 0x98 0x80\n");  
printf("We can output the 4 bytes like this: \xF0\x9F\x98\x80\n");  
printf("Or like this: ");  
putchar(0xF0);  
putchar(0x9F);  
putchar(0x98);  
putchar(0x80);  
putchar('\n');
```

source code for hello.c

# Converting Unicode Codepoints to UTF-8

```
uint8_t encoding[5] = {0};  
if (code_point < 0x80) {  
    encoding[0] = code_point;  
} else if (code_point < 0x800) {  
    encoding[0] = 0xC0 | (code_point >> 6);  
    encoding[1] = 0x80 | (code_point & 0x3f);  
} else if (code_point < 0x10000) {  
    encoding[0] = 0xE0 | (code_point >> 12);  
    encoding[1] = 0x80 | ((code_point >> 6) & 0x3f);  
    encoding[2] = 0x80 | (code_point & 0x3f);  
} else if (code_point < 0x200000) {  
    encoding[0] = 0xF0 | (code_point >> 18);  
    encoding[1] = 0x80 | ((code_point >> 12) & 0x3f);  
    encoding[2] = 0x80 | ((code_point >> 6) & 0x3f);  
    encoding[3] = 0x80 | (code_point & 0x3f);  
}
```

source code for utf8\_encode.c

# Converting Unicode Codepoints to UTF-8

```
printf("U+%x  UTF-8: ", code_point);
for (uint8_t *s = encoding; *s != 0; s++) {
    printf("0x%02x ", *s);
}
printf(" %s\n", encoding);
}

int main(void) {
    print_utf8_encoding(0x42);
    print_utf8_encoding(0x00A2);
    print_utf8_encoding(0x10be);
    print_utf8_encoding(0x1F600);
}
```

source code for utf8\_encode.c

# Summary of UTF-8 Properties

- Compact, but not minimal encoding; encoding allows you to resync immediately if bytes lost from a stream.
- ASCII is a subset of UTF-8 - complete backwards compatibility!
- All other UTF-8 bytes > 127 (0x7f)
  - no byte of multi-byte UTF-8 encoding is valid ASCII.
- No byte of multi-byte UTF-8 encoding is 0
  - can still use store UTF-8 in null-terminated strings.
- 0x2F (ASCII /) and 0x00 can not appear in multi-byte characters
  - hence can use UTF-8 for Linux/Unix filenames
- C programs can treat UTF-8 similarly to ASCII.
- Beware: number of bytes in UTF-8 string != number of characters.