# Lexical Rules and Data Types

CSC230: C and Software Tools

N.C. State Department of Computer Science

# Contents

- Lexical Scanning
- Comments
- Identifiers and Keywords
- C Variables
- Data Types
- Fundamental C Types
- Constants

# Compiling Step #1: *Lexical Scanning*

- Divides the program into *tokens*, which are the smallest meaningful units of a program
- Tokens in C are…
  - identifiers (e.g., **`num_records`**, **`cust_name`**)
  - keywords (e.g., **`while`**, **`if`**, **`char`**)
  - constants/strings (e.g., **`3.1415`**, **`"Answer: "`**)
  - operators (e.g., **`+`**, **`^`**, **`=`**)
  - explicit separators (e.g., **`(`**, **`}`**, **`;`**)

# Scanning… (cont'd)

- White space (space, tabs/indentation, newlines, comments) are ignored, except as explicit separators

# Scanning (cont'd)

- Not so easy: what are the tokens in `d=-c+++a;`

```
d  =   -c2   +   ++a   ;  ?
d  =   c2++   +   a   ;  ?
d  =-   c2++   +   a  ;  ?
d  =-   c2 + ++a;   ?
```

This is not a precedence issue

- we don't know or care what the precedence of `=`, `=-`, `++`, and `+` is at this point

# “Max Munch”

- Scan from left to right, always grabbing the largest token possible
- Example (again):

```
1.d  =-c2+++a;
```
(“d=“ not a token)

```
2.d  =  -  c2+++a;
```
(“=-” not a token)

```
3.d  =  -  c2+++a;
```
(“-c” not a token)

```
4.d  =  -  c2  +++a;
```
(“c2+” not a token)

```
5.d  =  -  c2  ++  +a;
```
(“+++” not a token)

```
6.d  =  -  c2  ++  +  a;
```
(“+a” not a token)

```
7.d  =  -  c2  ++  +  a  ;
```
(“a;” not a token)

# Scanning… (cont'd)

- How many tokens, and what are they?

```
j =+k2+3;
```

# Comments About Comments

- Block Style:

```
a = c - b;    /* b must be gt 0 */
d = a * 3;
```

Great for commenting out whole sections of code, but look out if the code already has comments!

terminates

```
/* Comment out the next two lines
 a = c - b;    /* b must be gt 0 */
 d = a * 3;
*/
```

☠ *common source of bugs* ☠

**attempt to nest comments**

# Comments (cont'd)

- To-end-of-line comments are allowed in C99:

```
r = 6 * x;   // compute radius
d = 2 * r;   // now diameter
```



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# Identifiers (Names, Labels)

- Consist of letters, '_', and digits
  - cannot start with a digit (`2_B_or_not_2_B`)🚫
- Case sensitive!
  - `myVar` is not the same as `myvar`
- Unlimited length (advice: stop at 32)
- `gnome_memmgt_insert_into_heap_I_modified_this_because_I_can`

# Reserved Keywords

- (do not use as identifiers)
- C89:
  - `auto`, **`break`**, **`case`**, **`char`**, **`const`**, **`continue`**, **`default`**, **`do`**, **`double`**, **`else`**, **`enum`**, `extern`, **`float`**, **`for`**, `goto`, **`if`**, **`int`**, **`long`**, `register`, **`return`**, **`short`**, **`signed`**, **`sizeof`**, **`static`**, **`struct`**, **`switch`**, **`typedef`**, **`union`**, **`unsigned`**, **`void`**, `volatile`, **`while`**
- C99 adds a few more:
  - **`_Bool`**, `_Complex`, `_Imaginary`, `inline`, `restrict`

# C Variables!

- A *variable* =
  a location in memory + its *interpretation*
- Interpretation of a variable is based on its
  1. *storage class* and
  2. *data type*

- *(We will discuss storage classes later…)*
  - *lifetime of the variable*
  - *how variable is (or can be) initialized*
  - *scope (visibility) of the variable*

# Data Types

- The data type of a variable defines its interpretation

- Ex: suppose a 32-bit binary value stored in memory is **01000001010000100100001101000100**
  - if type **`float`**, interpreted to be numerical value 781.03521728515625
  - if type **`unsigned int`**, interpreted to be numerical value 1145258561
  - if type **`char`**, interpreted to be the ASCII string value ABCD

# Static or Dynamic Types

- In C (and Java), variables are statically typed
  - type must be declared when variable is created, and cannot change thereafter
- Languages with dynamic typing (e.g., PHP, Python, Perl, Ruby, Javascript, …) are more flexible

# Fundamental C Types

- (also called built-in, primitive, basic types)
- There are really only 2!
  - integer (includes characters)
  - floating point, or limited precision real number

# *Derived* C Types

- These are composed from the fundamental types
  - arrays
  - functions
  - pointers
  - structs
  - unions
  - *these will all be discussed later…*
- Enumerated types*: we'll discuss later…*
- Complex numbers type: *we won't use this semester*

# Specializations of Fundamental Types

- Integers can be…
  - **signed** or **unsigned** (**signed** by default)
  - really short (**char**), **short**, regular (**int** by default), **long**, really long (**long long**)
- Floating point (always signed) can be…
  - regular precision (**float**)
  - double precision (**double**)
  - extended precision (**long double**)

# (Footnote)

- The data type of a variable defines its usual meaning, but the programmer may interpret it differently
- Ex.: a **`char`** can represent…
  - an ASCII-encoded character (most common case)
  - an 8-bit integer
  - eight 1-bit flags
  - …

# Min and Max Integer Values

- The lengths (in bits) (and the max and min values) of these types are platform dependent
- Common Platform (`/usr/include/limits.h`):

| Type | # bits | Value |
|---|---|---|
| Min ‘unsigned anything’ | n.a. | 0 |
| Min ‘signed char’ | 8 | -128 |
| Max ‘signed char’ | 8 | 127 |
| Max ‘unsigned char’ | 8 | 255 |
| Min ‘signed short’ | 16 | -32,768 |
| Max ‘signed short’ | 16 | 32,767 |
| Max ‘unsigned short’ | 16 | 65,535 |

# Integer Values… (cont'd)

| Type | # bits | Value |
| --- | --- | --- |
| Min 'signed int' | 32 | -2,147,483,648 |
| Max 'signed int' | 32 | 2,147,483,647 |
| Max 'unsigned int' | 32 | 4,294,967,295 |
| Min/Max 'signed long' | 64 | 9,223,372,036,854,775,808<br>-9,223,372,036,854,775,807 |
| Max 'unsigned long' | 64 | 18,446,744,073,709,551,615 |
| Min 'signed long long' | 64 | Same as long |
| Max 'signed long long' | 64 | Same as long |
| Max 'unsigned long long' | 64 | Same as long |

- Which is big enough to store the daily federal deficit?

# Floating Point (Real Numbers)

- Warning! Platform dependent! Lots of **gcc** options!
- Terminology

$$+.793 * 2^{-36}$$

sign of the mantissa — magnitude of the mantissa — base of the exponent — exponent

Size of the exponent (# bits) mainly determines the range of numbers that can be represented

Size of the mantissa (# bits) mainly determines the precision of numbers that can be represented

# Floating Point (Real Numbers)

- IEEE floating point standard single precision:
  - 1-bit sign
  - 23-bit (+ 1 implied bit) mantissa
  - 8-bit biased exponent (base 2)
  - 6 decimal digits precision

  (sign, mantissa, exponent: 32 bit)

- double precision:
  - 1-bit sign
  - 52+1 bit mantissa
  - 11-bit biased exponent (base 2)
  - 15 decimal digits precision

  (sign, mantissa, exponent: 64 bit)

# Floating Point (cont'd)

- Min (normalized) positive values (approximate)
  - single precision (**`float`**): $2^{-126}$ ($\approx 10^{-38}$ )
  - double precision (**`double`**): $2^{-1022}$ ($\approx 10^{-308}$)
  - Q: small enough to measure the diameter of an atom, in meters?
- Max (normalized) positive values (approximate)
  - single precision (**`float`**): $2^{127}$ ($\approx 10^{38}$)
  - double precision (**`double`**): $2^{1023}$ ($\approx 10^{308}$)
  - Q: big enough to count the number of atoms in the universe? distance to the edge of the observable universe, in units of atom diameters?

# Floating Point (cont'd)

- **`long double`** = 128 bits
  - more bits precision than **`double`**, same range

# Reminder: Arithmetic Problems

- Types make a difference in computer arithmetic
  - signed vs. unsigned max and min values (integer)
  - overflow (integer and floating point)
  - underflow and limited precision (floating point)
- More info about floating point:
  see CSC236 or CSC302

☠ *common source of bugs* ☠
**overflow, limits of precision**



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# What does this do?

```
int main()
{
    char i;
    for (i=0; i<200; i++) {
        printf("%d\n",i);
    }
}
```

```
0
1
2
3
...
125
126
127
-128
-127
-126
...
-3
-2
-1
0
1
2
3
...
125
126
127
-128
-127
-126
...
```

# Why?

```
int main()
{
    char i;
    for (i=0; i<200; i++) {
        printf("%4d %s\n",i,
               byte_to_binary(i));
    }
}
```

```
   0 00000000
   1 00000001
   2 00000010
   3 00000011
...
 125 01111101
 126 01111110
 127 01111111
-128 10000000
-127 10000001
-126 10000010
...
  -3 11111101
  -2 11111110
  -1 11111111
   0 00000000
   1 00000001
   2 00000010
   3 00000011
...
 125 01111101
 126 01111110
 127 01111111
-128 10000000
-127 10000001
-126 10000010
...
```

# How to fix?

*What word can go here?*

```
int main()
{
    [redacted] char i;
    for (i=0; i<200; i++) {
        printf("%4d %s\n",i,
            byte_to_binary(i));
    }
}
```

```
   0 00000000
   1 00000001
   2 00000010
   3 00000011
...
 197 11000101
 198 11000110
 199 11000111
```

# How to fix?

*What data type can go here?*

```
int main()
{
    ____ i;
    for (i=0; i<200; i++) {
        printf("%4d %s\n",i,
            byte_to_binary(i));
    }
}
```

```
  0 00000000
  1 00000001
  2 00000010
  3 00000011
...
197 11000101
198 11000110
199 11000111
```

# Constants with ‘const’

- Don’t want a value to change? Throw a **`const`** on there.

```
const int BUFFER_SIZE = 1024;
const double PI = 3.14159265358979323 8;
const char delimiter = ‘,’;
```

- Character constants in single quotes: **`'a'`**, **`'b'`**
  - value stored is the numeric value of the character in ASCII

# Constants with #define

## #define <CONSTANT_NAME> <value>

- Means "literally replace *CONSTANT_NAME* with *value* every time you see it in my file".
- Can be very dumb. What does this program do?

```
#define SLOPE -2
#define Y_INTERCEPT 1

int main()
{
    float x = 1;
    // find the y coordinate of this line
    float y = x SLOPE + Y_INTERCEPT;
    printf("Coords: (%f,%f)\n",x,y);
}
```

Missing * operator

Correct answer:
Coords: (1.000000,-1.000000)

Actual output:
Coords: (1.000000,0.000000)

# const vs. #define

- The ‘const’ keyword does other stuff we’ll learn later when it comes to arrays/pointers.
- Things can get complicated when it comes to using ‘const’ to declare constants between files; #define doesn’t have these issues.

- Result: Just use #define.

# ASCII

American Standard Code for Information Interchange

- ASCII is a specific 8-bit encoding of Western characters (punctuation, digits, upper and lower case characters)
- Only the first 128 values (decimal 0-127, octal 000-177) are standardized
- The interpretation of the remaining 128 values (decimal 128-255, octal 200-377) are not standardized, i.e., they are application/platform-specific

# Standardized ASCII (0-127)

| Dec | Hx | Oct | Char | | Dec | Hx | Oct | Html | Chr | Dec | Hx | Oct | Html | Chr | Dec | Hx | Oct | Html | Chr |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 000 | NUL | (null) | 32 | 20 | 040 |   | Space | 64 | 40 | 100 | @ | @ | 96 | 60 | 140 | ` | ` |
| 1 | 1 | 001 | SOH | (start of heading) | 33 | 21 | 041 | ! | ! | 65 | 41 | 101 | A | A | 97 | 61 | 141 | a | a |
| 2 | 2 | 002 | STX | (start of text) | 34 | 22 | 042 | " | " | 66 | 42 | 102 | B | B | 98 | 62 | 142 | b | b |
| 3 | 3 | 003 | ETX | (end of text) | 35 | 23 | 043 | # | # | 67 | 43 | 103 | C | C | 99 | 63 | 143 | c | c |
| 4 | 4 | 004 | EOT | (end of transmission) | 36 | 24 | 044 | $ | $ | 68 | 44 | 104 | D | D | 100 | 64 | 144 | d | d |
| 5 | 5 | 005 | ENQ | (enquiry) | 37 | 25 | 045 | % | % | 69 | 45 | 105 | E | E | 101 | 65 | 145 | e | e |
| 6 | 6 | 006 | ACK | (acknowledge) | 38 | 26 | 046 | & | & | 70 | 46 | 106 | F | F | 102 | 66 | 146 | f | f |
| 7 | 7 | 007 | BEL | (bell) | 39 | 27 | 047 | ' | ' | 71 | 47 | 107 | G | G | 103 | 67 | 147 | g | g |
| 8 | 8 | 010 | BS | (backspace) | 40 | 28 | 050 | ( | ( | 72 | 48 | 110 | H | H | 104 | 68 | 150 | h | h |
| 9 | 9 | 011 | TAB | (horizontal tab) | 41 | 29 | 051 | ) | ) | 73 | 49 | 111 | I | I | 105 | 69 | 151 | i | i |
| 10 | A | 012 | LF | (NL line feed, new line) | 42 | 2A | 052 | * | * | 74 | 4A | 112 | J | J | 106 | 6A | 152 | j | j |
| 11 | B | 013 | VT | (vertical tab) | 43 | 2B | 053 | + | + | 75 | 4B | 113 | K | K | 107 | 6B | 153 | k | k |
| 12 | C | 014 | FF | (NP form feed, new page) | 44 | 2C | 054 | , | , | 76 | 4C | 114 | L | L | 108 | 6C | 154 | l | l |
| 13 | D | 015 | CR | (carriage return) | 45 | 2D | 055 | - | - | 77 | 4D | 115 | M | M | 109 | 6D | 155 | m | m |
| 14 | E | 016 | SO | (shift out) | 46 | 2E | 056 | . | . | 78 | 4E | 116 | N | N | 110 | 6E | 156 | n | n |
| 15 | F | 017 | SI | (shift in) | 47 | 2F | 057 | / | / | 79 | 4F | 117 | O | O | 111 | 6F | 157 | o | o |
| 16 | 10 | 020 | DLE | (data link escape) | 48 | 30 | 060 | 0 | 0 | 80 | 50 | 120 | P | P | 112 | 70 | 160 | p | p |
| 17 | 11 | 021 | DC1 | (device control 1) | 49 | 31 | 061 | 1 | 1 | 81 | 51 | 121 | Q | Q | 113 | 71 | 161 | q | q |
| 18 | 12 | 022 | DC2 | (device control 2) | 50 | 32 | 062 | 2 | 2 | 82 | 52 | 122 | R | R | 114 | 72 | 162 | r | r |
| 19 | 13 | 023 | DC3 | (device control 3) | 51 | 33 | 063 | 3 | 3 | 83 | 53 | 123 | S | S | 115 | 73 | 163 | s | s |
| 20 | 14 | 024 | DC4 | (device control 4) | 52 | 34 | 064 | 4 | 4 | 84 | 54 | 124 | T | T | 116 | 74 | 164 | t | t |
| 21 | 15 | 025 | NAK | (negative acknowledge) | 53 | 35 | 065 | 5 | 5 | 85 | 55 | 125 | U | U | 117 | 75 | 165 | u | u |
| 22 | 16 | 026 | SYN | (synchronous idle) | 54 | 36 | 066 | 6 | 6 | 86 | 56 | 126 | V | V | 118 | 76 | 166 | v | v |
| 23 | 17 | 027 | ETB | (end of trans. block) | 55 | 37 | 067 | 7 | 7 | 87 | 57 | 127 | W | W | 119 | 77 | 167 | w | w |
| 24 | 18 | 030 | CAN | (cancel) | 56 | 38 | 070 | 8 | 8 | 88 | 58 | 130 | X | X | 120 | 78 | 170 | x | x |
| 25 | 19 | 031 | EM | (end of medium) | 57 | 39 | 071 | 9 | 9 | 89 | 59 | 131 | Y | Y | 121 | 79 | 171 | y | y |
| 26 | 1A | 032 | SUB | (substitute) | 58 | 3A | 072 | : | : | 90 | 5A | 132 | Z | Z | 122 | 7A | 172 | z | z |
| 27 | 1B | 033 | ESC | (escape) | 59 | 3B | 073 | ; | ; | 91 | 5B | 133 | [ | [ | 123 | 7B | 173 | { | { |
| 28 | 1C | 034 | FS | (file separator) | 60 | 3C | 074 | < | < | 92 | 5C | 134 | \ | \ | 124 | 7C | 174 | | | \| |
| 29 | 1D | 035 | GS | (group separator) | 61 | 3D | 075 | = | = | 93 | 5D | 135 | ] | ] | 125 | 7D | 175 | } | } |
| 30 | 1E | 036 | RS | (record separator) | 62 | 3E | 076 | > | > | 94 | 5E | 136 | ^ | ^ | 126 | 7E | 176 | ~ | ~ |
| 31 | 1F | 037 | US | (unit separator) | 63 | 3F | 077 | ? | ? | 95 | 5F | 137 | _ | _ | 127 | 7F | 177 | &#127; | DEL |



Source: www.LookupTables.com

# One Interpretation of 128-255

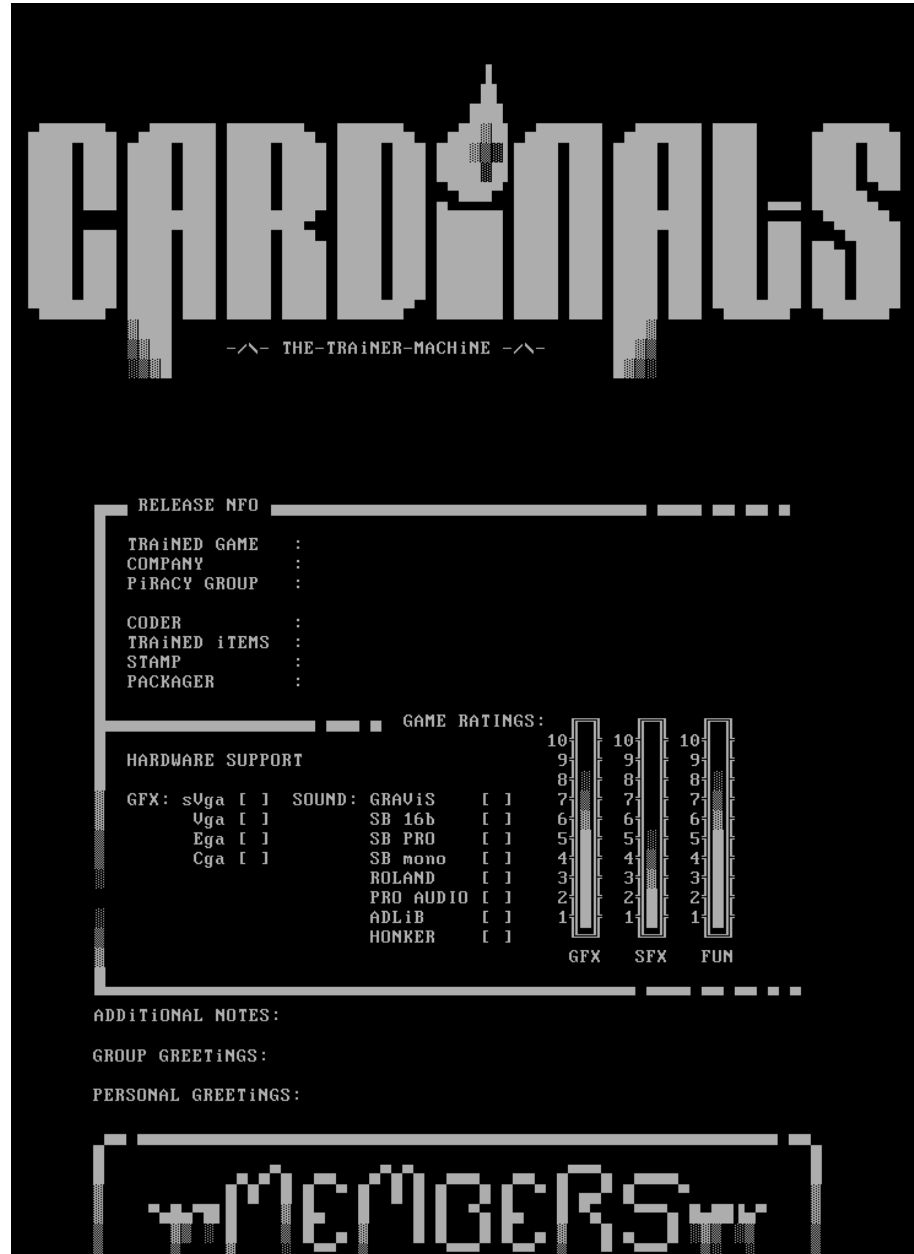
| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 128 | Ç | 144 | É | 161 | í | 177 | ▒ | 193 | ┴ | 209 | ╤ | 225 | ß | 241 | ± |
| 129 | ü | 145 | æ | 162 | ó | 178 | ▓ | 194 | ┬ | 210 | ╥ | 226 | Γ | 242 | ≥ |
| 130 | é | 146 | Æ | 163 | ú | 179 | │ | 195 | ├ | 211 | ╙ | 227 | π | 243 | ≤ |
| 131 | â | 147 | ô | 164 | ñ | 180 | ┤ | 196 | ─ | 212 | ╘ | 228 | Σ | 244 | ⌠ |
| 132 | ä | 148 | ö | 165 | Ñ | 181 | ╡ | 197 | ┼ | 213 | ╒ | 229 | σ | 245 | ⌡ |
| 133 | à | 149 | ò | 166 | ª | 182 | ╢ | 198 | ╞ | 214 | ╓ | 230 | µ | 246 | ÷ |
| 134 | å | 150 | û | 167 | º | 183 | ╖ | 199 | ╟ | 215 | ╫ | 231 | τ | 247 | ≈ |
| 135 | ç | 151 | ù | 168 | ¿ | 184 | ╕ | 200 | ╚ | 216 | ╪ | 232 | Φ | 248 | ° |
| 136 | ê | 152 | _ | 169 | _ | 185 | ╣ | 201 | ╔ | 217 | ┘ | 233 | Θ | 249 | · |
| 137 | ë | 153 | Ö | 170 | ¬ | 186 | ║ | 202 | ╩ | 218 | ┌ | 234 | Ω | 250 | · |
| 138 | è | 154 | Ü | 171 | ½ | 187 | ╗ | 203 | ╦ | 219 | █ | 235 | δ | 251 | √ |
| 139 | ï | 156 | £ | 172 | ¼ | 188 | ╝ | 204 | ╠ | 220 | ▄ | 236 | ∞ | 252 | _ |
| 140 | î | 157 | ¥ | 173 | ¡ | 189 | ╜ | 205 | ═ | 221 | ▌ | 237 | φ | 253 | ² |
| 141 | ì | 158 | _ | 174 | « | 190 | ╛ | 206 | ╬ | 222 | ▐ | 238 | ε | 254 | ■ |
| 142 | Ä | 159 | ƒ | 175 | » | 191 | ┐ | 207 | ╧ | 223 | ▀ | 239 | ∩ | 255 | |
| 143 | Å | 160 | á | 176 | ░ | 192 | └ | 208 | ╨ | 224 | α | 240 | ≡ | | |



Source: www.LookupTables.com

# (This allowed totally sweet ASCII art in the 90s)

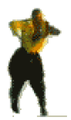





Sources:

- http://roy-sac.deviantart.com/art/Cardinal-NFO-File-ASCII-35664604
- http://roy-sac.deviantart.com/art/Siege-ISO-nfo-ASCII-Logo-35940815
- http://roy-sac.deviantart.com/art/deviantART-ANSI-Logo-31556803

# Useful Character Constant Escape Sequences

- **\0** Null character
- **\'** Single quote
- **\"** Double quote
- **** Backslash
- **\n** Newline 
- **\t** Horizontal tab
- **\nnn** Octal value of character (ex: **'a'** == **'\141'**)
- **\xnn** Hexadecimal value of character (== **'\x61'**)



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# Converting ASCII digits to Integers

- You can read ASCII characters and do arithmetic on them, but results not what you expect!
- Program: read a number, print it out

```
int c;
c = getchar();      // read one ascii character
printf("%d\n", c);// interpret c as an integer
                    // and print as ASCII
                    // (decimal) string
```

Result

- user types: 1
- program prints: 49

**Why??**

☠ *common source of bugs* ☠

**difference between ASCII-encoded strings and numbers**

# Converting ASCII to Numbers

- Converting ASCII-encoded digit to an integer, the right way:

```
unsigned char c;
c = (unsigned char) getchar();
unsigned int n;
n = c - '0';
printf("%d\n", n);
```

**Demo...**

| | | | | |
|---|---|---|---|---|
| 48 | 30 | 060 | 0 | 0 |
| 49 | 31 | 061 | 1 | 1 |
| 50 | 32 | 062 | 2 | 2 |
| 51 | 33 | 063 | 3 | 3 |
| 52 | 34 | 064 | 4 | 4 |
| 53 | 35 | 065 | 5 | 5 |
| 54 | 36 | 066 | 6 | 6 |
| 55 | 37 | 067 | 7 | 7 |
| 56 | 38 | 070 | 8 | 8 |
| 57 | 39 | 071 | 9 | 9 |

Converting integer to ASCII:

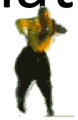
```
c = (char) (n + '0');
```

How would we convert an ASCII string ("12") to an integer, and vice versa???

# ("Wide" Characters)

- For encoding character sets other than ASCII
- Type: `wchar_t`
- Ex. of specifying a wide character constant: `L'å'`
- *We'll look at support for this later*

# String Literals

- Strings are arrays of characters
  - terminated (automatically, by the compiler) with **`NULL`** 
  - *we'll discuss more later…*
- Specifying a string: **`"abcdefg"`**
  - cannot contain double quote or span multiple lines (use **`\"`** or **`\n`** if quote or newline should be in the string)
  - strings of wide characters: **`L"å∫ç∂f"`**
- Warning: **`"a"`** is not the same as **`'a'`** !

# Multi-line string literals

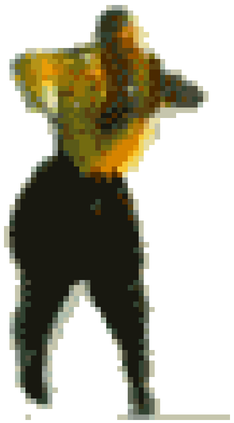
- Just put quoted string literals one after another; they get glued together automatically.

```
int main()
{
    printf("Usage:\n"
           "  coolapp [options] <filename>\n"
           "\n"
           "Copyright 2014 Tyler Bletsch\n");

}
```

# Review: Binary

- Advice: memorize the following (need for 236 anyway…)
  - $2^0 = 1$
  - $2^1 = 2$
  - $2^2 = 4$
  - $2^3 = 8$
  - $2^4 = 16$
  - $2^5 = 32$
  - $2^6 = 64$
  - $2^7 = 128$
  - $2^8 = 256$
  - $2^9 = 512$
  - $2^{10} = 1024$



# Review: decimal to binary

| ? | Quotient | Remain-der |
|---|---|---|
| 457 ÷ 2 = | 228 | 1 |
| 228 ÷ 2 = | 114 | 0 |
| 114 ÷ 2 = | 57 | 0 |
| 57 ÷ 2 = | 28 | 1 |
| 28 ÷ 2 = | 14 | 0 |
| 14 ÷ 2 = | 7 | 0 |
| 7 ÷ 2 = | 3 | 1 |
| 3 ÷ 2 = | 1 | 1 |
| 1 ÷ 2 = | 0 | 1 |

**111001001**

# Practice: binary to/from hex

- $0101101100100011_2$ -->
- $0101\ \ 1011\ \ 0010\ \ 0011_2$ -->
- 5 B 2 $3_{16}$

1 F 4 $B_{16}$ -->

$0001\ \ 1111\ \ 0100\ \ 1011_2$ -->

$0001111101001011_2$

| Binary | Hex |
|---|---|
| 0000 | 0 |
| 0001 | 1 |
| 0010 | 2 |
| 0011 | 3 |
| 0100 | 4 |
| 0101 | 5 |
| 0110 | 6 |
| 0111 | 7 |
| 1000 | 8 |
| 1001 | 9 |
| 1010 | A |
| 1011 | B |
| 1100 | C |
| 1101 | D |
| 1110 | E |
| 1111 | F |

# Integer Constants

- Specifying:
  *<optionalsign> <stringofdecimaldigits>*
  - ex: **`7940`**, **`+7940,  -36`**
- If prefixed by `0`, interpreted as base 8 constant
  - only `0-7` allowed as digits
- If prefixed by **`0x`**, interpreted as base 16 constant
  - **`0-9`**, **`a-f`** allowed as digits
- Ex.: what's decimal value of `03`, **`0x03`**, **`3`** ?
  of `53`, `053`, and **`0x53`** ?

# Integer Constants (cont'd)

- If suffixed by **`u`**, type is **`unsigned int,`** and value must be positive
  - ex: **`123u`**
- If suffixed by **`L`**, type is **`long int`**
  - ex: **`456L`**

# Floating Point Constants

- Specifying:
  *<optionalsign> integerpart* **.** *fractionpart*
  - either integer part or fractional part can be missing
  - all good: `22.22`, `+2.`, `-.22`
  - warning: `2` is integer constant, `2.` is floating point
- Followed (optionally) by exponent (expressed in base 10)
  - specifying:
    **e** *<optionalsign> <integerconstant>*
  - ex.: `23.45e-67` means $23.45 * 10^{-67}$

# Floating Point… (cont'd)

- Default type is **`double`**
  - suffixed by **`f`**: force type to be **`float`**
  - suffixed by **`L`**: **`long double`** (extended precision)
- *More about floating point numbers, precision, and range, later…*

# A dumb thing that C will let you do, but you shouldn’t do it

- The following is legal C code:

```
unsigned x;
```

- What’s the data size?
  - Yeah, I don’t know either
  - Apparently it’s like an int?
  - Let’s just never do this
- Always put the type specifier:

```
unsigned int x;
```

# tl;dr

| Integer Type | Size (on x86!) | Normal use | Signed range (on x86) | Unsigned range (on x86) |
|---|---|---|---|---|
| **char** | 8 bit (1 byte) | ASCII character or small integer | -128..127 | 0..255 |
| **short** | 16 bit (2 byte) | Smallish integer | -32768..32767 | 0..65535 |
| **int** | 32 bit (4 byte) | Normal integer | -2147483648.. 2147483647 | 0..4294967295 |
| **long** | 64 bit (8 byte) | Big integer | $-2^{63}+1$ .. $2^{63}-1$<br>-9,223,372,036,854,775,808.. 9,223,372,036,854,775,807 | 0.. $2^{64}-1$<br>18,446,744,073,709,551,615 |
| long long | 64 bit (8 byte) | Big integer | -9,223,372,036,854,775,808.. 9,223,372,036,854,775,807 | 18,446,744,073,709,551,615 |

| Decimal Type | Size (on x86!) | Normal use | Decimal digits of precision |
|---|---|---|---|
| float | 32 bit (4 byte) | Lousy decimal | 6 |
| **double** | 64 bit (8 byte) | Good decimal | 15 |

# Exercise 03a

## ASCII table

- Write a program that prints ASCII characters 32-127.
- Steps to help you along:
  - Write a loop to print integers 32..127.
  - Write a printf statement that prints a single character.
  - Combine them.

We haven't necessarily covered everything to do this. **Ask questions!**



**Reminder**: Go to course web page for link to exercise form.
Paste code into ideone.com and submit the link.



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# BACKUP

# Implied Types of Constants

- Default type for integer constants: shortest type compatible with value, starting with **`signed int`** -> **`unsigned int`** -> …
- Default type for floating point constants: **`double`**

# Base Conversions to/from Binary

…and be able to do the following

- $2*8^2 + 5*8^1 + 6*8^0$ == decimal 174 ==
- octal 256 ==
- binary 10 101 110 ==
- $2^7 + 2^5 + 2^3 + 2^2 + 2^1$ ==
- 128 + 32 + 8 + 4 + 2 == decimal 174

…and likewise with hex

# Review: binary to/from octal

- $00111000_2$ -->
- $00\ 111\ 000_2$ -->
- $0 \quad 7 \quad 0_8$

| Binary | Octal |
|---|---|
| 000 | 0 |
| 001 | 1 |
| 010 | 2 |
| 011 | 3 |
| 100 | 4 |
| 101 | 5 |
| 110 | 6 |
| 111 | 7 |

$356_8$ -->

$11\ 101\ 110_2$ -->

$11101110_2$