# C Fundamentals and Console I/O

ITSC 2181: Introduction to Computer Systems
UNC Charlotte
College of Computing and Informatics

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# C Coding Style (Conventions)

- Universal agreement
  1. clarity and consistency are very important
  2. indentation, white space, and comments helpful
  3. consistent naming conventions helpful
- Tools (intelligent editors, *indent*, etc.) will take care of much formatting for you.

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## Does it Matter?

Consider the following entries from the International Obfuscated C Code (IOCC) Contest…

**ob·fus·cate**: render obscure, unclear, or unintelligible: *the spelling changes will deform some familiar words and obfuscate their etymological origins*.

```
 #include\
                                  <stdio.h>
                     #include                <stdlib.h>
                     #include                <string.h>

                    #define w "Hk~HdA=Jk|Jk~LSyL[{M[wMcxNksNss:"
                   #define r"Ht@H|@=HdJHtJHdYHtY:HtFHtF=JDBIl"\
                  "DJTEJDFIlMIlM:HdMHdM=I|KIlMJTOJDOIlWITY:8Y"
                 #define S"IT@I\\@=HdHHtGH|KILJJDIJDH:H|KID"\
                "K=HdQHtPH|TIDRJDRJDQ:JC?JK?=JDRJLRI|UItU:8T"
               #define _(i,j)L[i=2*T[j,O[i=O[j-R[j,T[i=2*\
              R[j-5*T[j+4*O[j-L[j,R[i=3*T[j-R[j-3*O[j+L[j,
             #define t"IS?I\\@=HdGHtGIDJILIJDIItHJTFJDF:8J"

    #define y                  yy(4),yy(5),                yy(6),yy(7)
  #define yy(              i)R[i]=T[i],T[i ]            =O[i],O[i]=L [i]
#define Y _(0          ], 4] )_ (1 ], 5] )_ (2      ], 6] )_ (3 ], 7] )_=1
#define v(i)(      (( R[ i ] * _ + T [ i ]) * _ + O [ i ]) * _ + L [ i ]) *2
double b = 32  ,l ,k ,o ,B ,_ ; int Q , s , V , R [8 ], T[ 8] ,O [8 ], L[ 8] ;
#define q( Q,R ) R= *X ++ % 64 *8 ,R |= *X /8 &7 ,Q=*X++%8,Q=Q*64+*X++%64-256,
# define  p      "G\\QG\\P=GLPGTPGdMGdNGtOGlOG"   "dSGdRGDPGLPG\\LG\\LHtGHtH:"
#  define W         "Hs?H{?=HdGH|FI\\II\\GJlHJ"    "lFL\\DLTCMlAM\\@Ns}Nk|:8G"
# define   U           "EDGEDH=EtCElDH{~H|AJk}"       "Jk?LSzL[|M[wMcxNksNst:"
#  define u                  "Hs?H|@=HdFHtEI"             "\\HI\\FJLHJTD:8H"
char  *   x                   ,*X , ( * i )[              640],z[3]="4_",
*Z = "4,804.804G" r U "4M"u S"4R"u t"4S8CHdDH|E=HtAIDAIt@IlAJTCJDCIlKI\\K:8K"U
 "4TDdWDdW=D\\UD\\VF\\FFdHGtCGtEIDBIDDIlBIdDJT@JLC:8D"t"4UGDNG\\L=GDJGLKHL\
FHLGHtEHtE:"p"4ZFDTFLT=G|EGlHITBH|DIlDIdE:HtMH|M=JDBJLDKLAKDALDFKtFKdMK\
\\LJTOJ\\NJTMJTM:8M4aGtFGlG=G|HG|H:G\\IG\\J=G|IG|I:GdKGlL=G|JG|J:4b"W
S"4d"W t t"4g"r w"4iGlIGlK=G|JG|J:4kHl@Ht@=HdDHtCHdPH|P:HdDHdD=It\
BIlDJTEJDFIdNI\\N:8N"w"4lID@IL@=HlIH|FHlPH|NHt^H|^:H|MH|N=J\\D\
J\\GK\\OKTOKDXJtXItZI|YIlWI|V:8^4mHLGH\\G=HLVH\\V:4n" u t t
"4p"W"IT@I\\@=HdHHtGIDKILIJLGJLG:JK?JK?=JDGJLGI|MJDL:8M4\
rHt@H|@=HtDH|BJdLJTH:ITEI\\E=ILPILNNtCNlB:8N4t"W t"4u"
p"4zI[?Il@=HlHH|HIDLILIJDII|HKDAJ|A:JtCJtC=JdLJtJL\
THLdFNk|Nc|\
:8K"; main (
int C,char**        A) {for(x=A[1],i=calloc(strlen(x)+2,163840);
C-1;C<3?Q=_=       0,(z[1]=*x++)?((*x++==104?z[1]^=32:--x), X =
strstr(Z,z))      &&(X+=C++):(printf("P2 %d 320 4 ",V=b/2+32),
V*=2,s=Q=0,C     =4):C<4?Q-->0?i[(int)((l+=o)+b)][(int)(k+=B)
]=1:_?_-=.5/    256,o=(v(2)-(l=v(0)))/(Q=16),B=(v(3)-(k=v(1)
))/Q:*X>60?y   ,q(L[4],L[5])q(L[6],L[7])*X-61||(++X,y,y,y),
Y:*X>57?++X,  y,Y:*X >54?++X,b+=*X++%64*4:--C:printf("%d "
,i[Q][s]+i[Q ][s+1]+i[Q+1][s]+i[Q+1][s+1])&&(Q+=2)<V||(Q=
0,s+=2)<640
||(C=1));}
```

What is the purpose of this program?

```c
            /*                                      ,*/
           #include                              <time.h>
            #include/*                        _  ,o*/  <stdlib.h>
            #define  c(C)/*     -      . */return      ( C); /*    2004*/
             #include   <stdio.h>/*.   Moekan             "'   `\b-'     */
               typedef/*  */char   p;p* u                       ,w       [9
                 ][128] ,*v;typedef  int _;_   R,i,N,I,A               ,m,o,e
            [9],  a[256],k    [9], n[               256];FILE*f       ;_ x   (_ K,_ r
       ,_ q){;   for(;                                         r<     q    ; K       =((
    0xffffff)   &(K>>8))^                                       n[255     &         ( K
  ^u[0        +                                    r  ++      ]     )]);c           (K
 )}        _ E                          (p*r,    p*q  ){     c(           f          =
        fopen                         (r  ,q))}_   B(_ q){c(    fseek         (f,      0
      ,q))}_ D(){c(  fclose(f ))}_  C(  p    *q){c(  0-    puts(q     )    )}_/*   /
    */main(_ t,p**z){if(t<4)c(   C("<in"       "file>"    "\40<l"    "a"  "yout> "
   /*b9213272*/"<outfile>"   ) )u=0;i=I=(E(z[1],"rb")) ?B(2)?0 :   (((o   =ftell
  (f))>=8)?(u     =(p*)malloc(o))?B(0)?0:!fread(u,o,1,f):0:0)?0:  D():0      ;if(
 !u)c(C("      bad\40input  "));if(E(z[2],"rb" )){for(N=-1;256> i;n[i++] =-1   )a[
 i]=0;       for(i=I=0;   i<o&&(R  =fgetc(   f))>-1;i++)++a[R] ?(R==N)?( ++I>7)?(n[
N]+1       )?0:(n [N   ]=i-7):0:   (N=R)    |(I=1):0;A =-1;N=o+1;for(i=33;i<127;i++
)(        n[i   ]+  1&&N>a[i])?    N= a     [A=i]     :0;B(i=I=0);if(A+1)for(N=n[A];
I<       8&&   (R  =fgetc(f ))>   -1&& i   <o         ;i++)(i<N||i>N+7)?(R==A)?((*w[I
]              =u [i])?1:(*w[I]=   46))?(a            [I++]=i):0:0:0;D();}if(I<1)c(C(
              "  bad\40la" "yout  "))for(i           =0;256>(R=  i);n[i++]=R)for(A=8;
             A  >0;A --)   R  = ( (R&1)==0)          ?(unsigned int)R>>(01):((unsigned
            /*kero  Q'        ,KSS  */)R>>          1)^       0xedb88320;m=a[I-1];a[I
            ]=(m          <N)?(m=   N+8):        ++        m;for(i=00;i<I;e[i++]=0){
           v=w          [i]+1;for(R                       =33;127  >R;R++)if(R-47&&R-92
           &&       R-(_)* w[i])*(                     v++)=    (p)R;*v=0;}for(sprintf
                 /*'_  G*/  (*w+1,                 "%0"     "8x",x(R=time(i=0),m,o)^~
               0)   ;i<       8;++              i)u      [N+ i]=*(*w+i+1);for(*k=x(~
                 0,i=0     ,*a);i>-        1;      ){for (A=i;A<I;A++){u[+a [ A]
               ]=w[A       ][e[A]]  ;     k     [A+1]=x (k[A],a[A],a[A+1]
             );}if     (R==k[I])      c(      (E(z[3  ],"wb+"))?fwrite(
            /* */   u,o,1,f)?D          ()|C("  \n    OK."):0    :C(
           "  \n  WriteError"           ))  for  (i  =+I-
          1  ;i >-1?!w[i][++                e[+ i]]:0;
            ) for( A=+i--;                A<I;e[A++]
            =0); (i <I-4                 )?putchar
            ((_   )  46)                  | fflush
           /*'      ,*/                  ( stdout
           ):       0&                    0;}c(C
          ("       \n                   fail")
          )      /*                    dP' /
                dP                    pd  '
               '                      zc
                                     */
                                    }
```

```c
[I++]=i):0:0:0;D(
);}if(I<1)c(C("
bad\40la""yout"))
for(i=0;256>(R=i)
;n[i++]=R)for(A=8
;A>0;A--
)R=((R&1)==0)?(un
signed
int)R>>(01):((uns
igned/*kero
Q',KSS
*/)R>>1)^0xedb883
20;m=a[I-
1];a[I]=(m
<N)?(m=N+8):++m;f
or(i=00;i<I;e[i++
]=0){
```

## Ex.: Some GNOME Project Guidelines

- "Programmers should strive to write good code so that it is easy to understand and modify by others
- Important qualities of good code
  - clarity
  - consistency
  - extensibility
  - correctness"

## Example… (cont’d)

- “It is important to follow a good naming convention for the symbols in your programs
  - Function names should be of the form **`module_submodule_operation`**, for example, **`gnome_canvas_set_scroll_region`**
  - Symbols should have descriptive names: do not use **`cntusr()`**, use **`count_active_users()`** instead
  - Function names are lowercase, with underscores to separate words, like this: **`gnome_canvas_set_scroll_region()`**”

## Example… (cont'd)

- "Macros and enumerations are uppercase, with underscores to separate words, like this: **`GNOMEUIINFO_SUBTREE()`** for a macro
- Typedefs and structure names are mixed upper and lowercase, like this: **`GnomeCanvasItem`**, **`GnomeIconList`**"

## Example… (cont’d)

- “Very short and terse names should only be used for the local variables of functions; never call a global variable **`x`**; use a longer name that tells what it does”

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# Example from Linux Guidelines

- “Tabs are 8 characters, and indentations too
- Put the opening brace last on the line, and put the closing brace first:

```
if (x is true) {
  we do y
}
```

- Functions have the opening brace at the beginning of the next line:

```
int function(int x)
{
  body of function
}”
```

# Our Guidelines! (These Matter!)

- Make sure to include file level comments in all programs
  - Author(s) name and UNC Charlotte email address(s)
  - Briefly describe the purpose of program or module within program
- Use function comments
  - Function's purpose
  - Inputs (global or parameters)
  - Outputs (return values and side effects)
  - Pre-conditions
  - Post-conditions (including side effects)

# Our Guidelines! (These Matter!)

- Global Variables
  - Describe purpose
- Magic Numbers
  - Use `#define` except for obvious numbers (-1, 0, 1, 2)
    - Unless those numbers have a specific named purpose or are an exit code!!!
    - We cover `#define` in more detail later.

# Our Guidelines! (These Matter!)

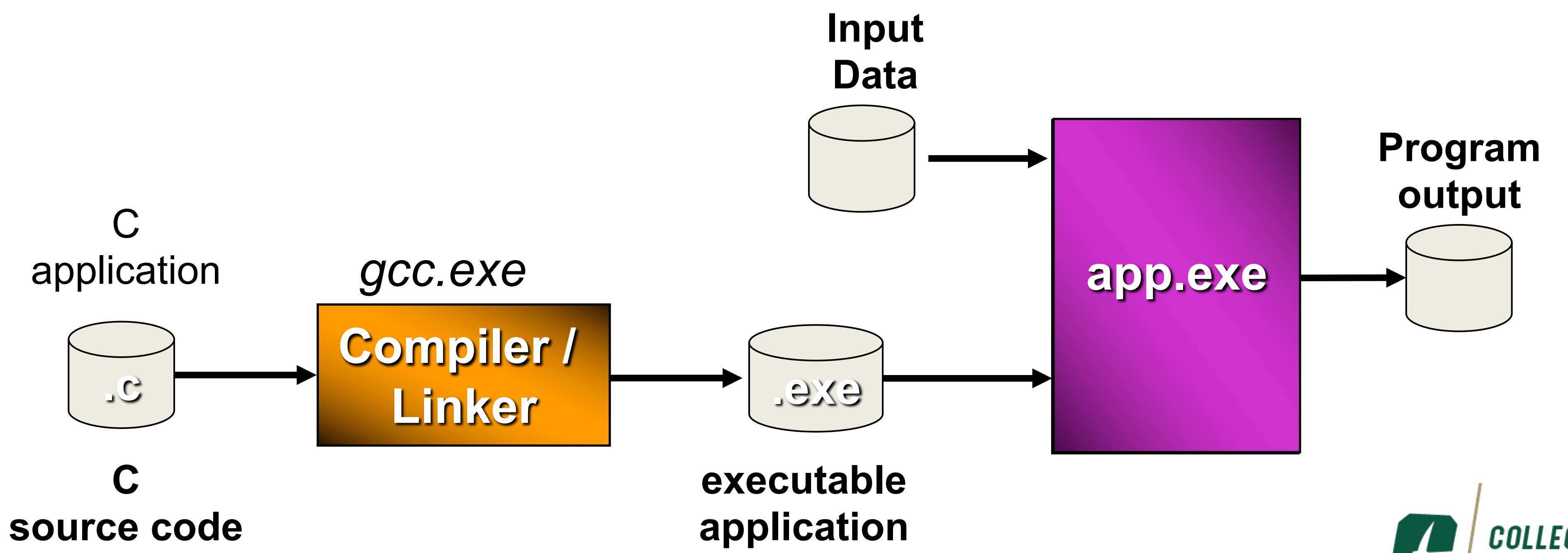
- Indentation
  - All indentation must be spaces (except for Makefiles)
  - The number of spaces for indentation must be consistent
    - 2 to 3 spaces
  - Indent:
    - Statements in a function
    - Statements in a control structure
    - Statements in a block { }

## Our Guidelines! (These Matter!)

- Curly Braces
  - Functions – opening curly brace on next line
  - Everything else – opening curly brace at end of control structure
- Statements
  - 1 statement per line

# Executing C Programs

1. High-Level Language (HLL) source code is **compiled** into the instruction set of the target computer
2. This code is loaded and **executed directly** by the host



## Platform Independence?

- Compiled
  - parts of the compiler (*front end*) are platform-independent
  - parts of the compiler (*back end*) are specific to the platform on which the program will be executed
- Interpreted
  - the Java compiler is platform-independent
  - the Java Virtual Machine (JVM) is platform-specific

# Steps in Compiling C Programs

Source Code

```
#define N 3
a=c+b*N;
```

↓ ***preprocessing***

Expanded Source Code

```
a=c+b*3;
```

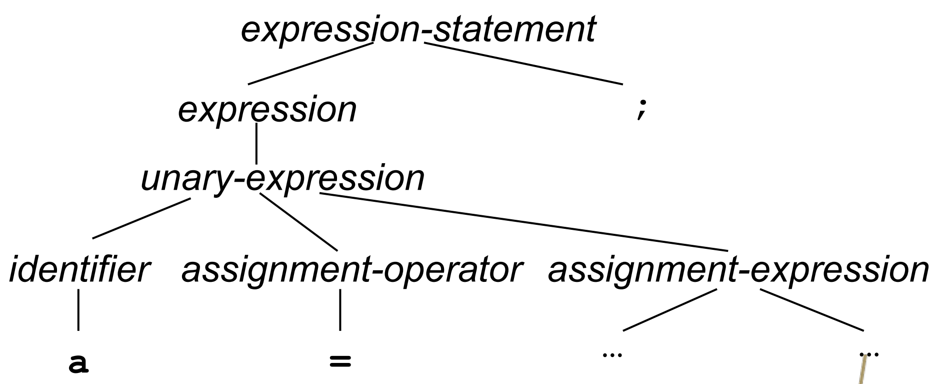
↓ ***lexical analysis***

Tokens

```
a   =   c   +   b   *   3   ;
```

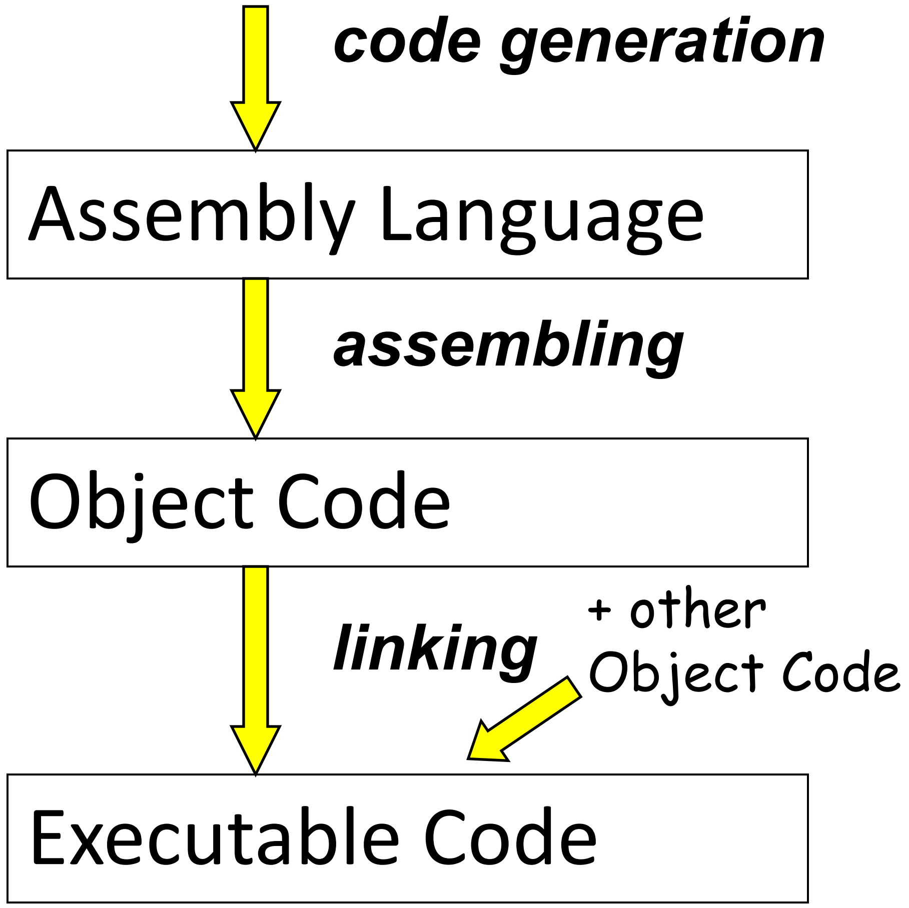
↓ ***parsing***

Parse Tree



↓ ***code generation***

## Steps… (cont'd)



```
mov ebx, b
imul ebx, ebx, 3
mov ecx, c
```

```
001110010111
```

```
00111001011101101...
```

## Using the **`gcc`** Compiler

- **`gcc`** is a high-quality, open source compiler available for most platforms
- At the command prompt, type

```
gcc   -Wall -std=c17 pgm.c
```

where *pgm.c* is the C program source file

  - Creates an executable **`a.out`**
  - **`-std=c99`** specifies that C99 standard features are allowed
  - **`-Wall`** turns on all the important **warning messages**

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## Compiler… (cont’d)

- GNOME (and me): “Make sure your code compiles with absolutely no warnings from the compiler. These help you catch stupid bugs.”

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## Some Useful **gcc** Options

| | |
|---|---|
| `-c` | Compile the source code but do not link (i.e., produce only the object file) |
| `-E` | Preprocess the source code only (i.e., expand macros, but do not compile the source code) |
| `-o` ***file*** | Put output in file named **file** |
| `--version` | Display version number of gcc |
| `-std=c17` | Support C17 (2017) language features |
| `-Wall` | Enable all warnings |
| `-g` | Produce information necessary to debug using **gdb** |

# **gcc** options... (cont’d)

| | |
|---|---|
| **-O, -O1** | Various optimization levels |
| **-D *name*** | Define name as a macro with value 1 (used for conditional compilation) |
| **-l*lib*** | Search named **library** when linking |
| **-I*dir*** | Add directory **dir** to the head of the list of directories to search for header files |
| **-L*dir*** | Add directory **dir** to the list of directories to search for libraries containing object files (specified using the **-l** option) |
| **-S** | Performs preprocessing and compilation steps. Generates assembly instructions. |

# C Language Standards

- There are multiple generations of C
  - K&R C
  - C89 (or C90)
  - **C99**
  - C11, C17 and C23

ISO standards

- **We will use the default C standard supported by gcc**
  - To compile code for a specific standard, use the -std compiler directive. For example: -std=c11 to use C11.
  - The latest standard in wide use is C11.

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## Console I/O

## What is I/O ?

- The **I** stands for **Input**, that is, the data entered by the user or read by the program from an external source.
  - External sources in C are usually referred to as *streams*. A text file and the console (terminal) are examples of streams.
- The **O** stands for **Output**, that is, the results produced by the program code.
  - Output in C is sent to a stream.
  - By default, C programs use the computer’s console or terminal.
  - We will use the console and text files as the output stream.

# Console I/O in C

- I/O is provided by **standard library** functions
  - available on **all platforms**
- To use, your program must have

```
#include <stdio.h>
```

- …and it doesn't hurt to also have

```
#include <stdlib.h>
```

- *These are **preprocessor** statements; the .h files define function types, parameters, and constants from the standard library.*

## Streams

- A ***stream*** is a **file** or a **device** from which data is read, and/or to which data is written
- By **default**, every C program automatically has 3 open streams, called
  - the *standard input*
  - the *standard output*
  - the *standard error*

## Streams (cont'd)

- If you do not override them…
  - standard input means the keyboard, i.e., what the user types.
  - standard output & error means the terminal window.

# The `printf()` function

- `printf()` is a **library function** for formatted output, with built-in conversions of input parameters to printable form.

- Definition: `int printf(const char * format, …)`

  Variable number of arguments

- `format` specifies how input arguments must be converted/formatted for output.

# Parts of `format`

1. **%** (mandatory)
2. 0 or more **flags** (infrequently used)
3. **Minimum output field width** (pad with spaces) (useful for making things line up)
4. **.Precision** (minimum number of digits to right of decimal point)
   (optional, default is 6 digits)
5. **type of format conversion** (mandatory)

# Precision Matters

- `printf` the number 33.3:

| **Format Specifier** | **Output** |
|---|---|
| `%7.1f` | `   33.3` |
| `%14.10f` | ` 33.2999992371` |
| `%.20f` | `33.29999923706054687500` |

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## Some Types of Conversions

| **Print as Type…** | **Specifier** |
|---|---|
| **`char`** | **`%c`** |
| **`unsigned int`** | **`%u`** (in **decimal**)<br>**`%o`** (in **octal**)<br>**`%x`**, **`%X`** (in **hex**)<br>**(`%lu`**, **`%lo`**, **`%lx`** for long) |
| **`signed int`** | **`%d`**, **`%i`** (in **decimal**)<br>(**`%ld`**, **`%li`** for long) |
| **`float`** | **`%f`** |
| **`float`** | **`%e`**, **`%E`** (use scientific notation) |
| (string) | **`%s`** |

# Example

Program:

```
char c = ‘a’;
int i = 9999;
float f = 3.1415926535897932;

printf(“c = %c (%o in octal)\n”, c, c);
printf(“i = %6d (%x in hex)\n”, i, i);
printf(“f = %8.5f (%e in sci. notation)\n”,
        f, f);
```

(see `format.c` in *Code samples and Demonstrations* in *Canvas*)

Output:

```
c = a (141 in octal)
i =   9999 (270f in hex)
f =  3.14159 (3.141593e+00 in sci. notation)
```

## The `scanf()` function

- `scanf()` is a **library function** for formatted input:
  - Converts numbers to/from ASCII
  - Skips “white space” automatically
- Definition: `int scanf(const char * fmt, …)`
  - Variable number of arguments
- `fmt` specifies how input must be converted.

## Examples

```
char c, d;
float f, g;
int i, j;
int result;

result = scanf("%c %c", &c, &d);
…check result to see if returned value 2…

result = scanf("%d %f %f", &i, &f, &g);
…check result to see if returned value 3…

result = scanf("%d", &i);
…check result to see if returned value 1…
```

(see `scanf_examples.c` in *Code samples and Demonstrations* in *Canvas*)

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## Parts of the Format Specifier

1. % (mandatory)
2. Minimum input field width (optional, number of characters to scan)
3. Type of format conversion (mandatory)

**NOTE**: White space in the format string does not force white space to be present in the input stream.

(see `date.c` in *Code samples and Demonstrations* in *Canvas*)

## Some Types of Conversions

| Convert input to Type… | Specifier |
|---|---|
| `char` | `%c` |
| `unsigned int` | `%u` (in decimal)<br>`%o` (in octal)<br>`%x`, `%X` (in hex)<br>(`%lu`, `%lo`, `%lx` for long) |
| `signed int` | `%d`, `%i` (in decimal)<br>(`%ld`, `%li` for long) |
| `float` | `%f` |
| `float` | `%e`, `%E` (use scientific notation) |
| (string) | `%s` |

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# Input Arguments to scanf()

- Must be passed using "call by reference", so that **`scanf()`** can overwrite their value
  - Pass memory address of the argument using **&** operator
- Example:

```
char c;
int j;
double num;
int result;

result = scanf("%c %d %lf", &c, &j, &num);
```

☠ *common source of bugs* ☠
**failure to use & before arguments to scanf**

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## Advice on `scanf()`

- **Experiment** with it and make sure you understand how it works, how the format specifier affects results
  - The assigned readings and reference materials are excellent resources on how different input strings are processed
- Always **check return value** to see if you read the number of values you were expecting

(see `scanf_examples.c` in *Code samples and Demonstrations* in *Canvas*)

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## `scanf()` Example

```
char x, y;
int j;
scanf("%c%c%d", &x, &y, &j);
```

Results with input

```
12345678912345678?

1 2 345678912345 1234?
```

(see `scanf_examples.c` in *Code samples and Demonstrations* in *Canvas*)

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## References

- S. J. Matthews, T. Newhall and K. C. Webb, *Dive into Systems*, Version 1.2. Free online textbook, available at: https://diveintosystems.org/book/

- K. N. King, *C Programming: A Modern Approach*, 2nd Edition. W. W. Norton & Company. 2008.

- D.S. Malik, *C++ Programming: From Problem Analysis to Program Design*, Seventh Edition. Cengage Learning. 2014.

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