Functions in C

ITCS 2116: C Programming

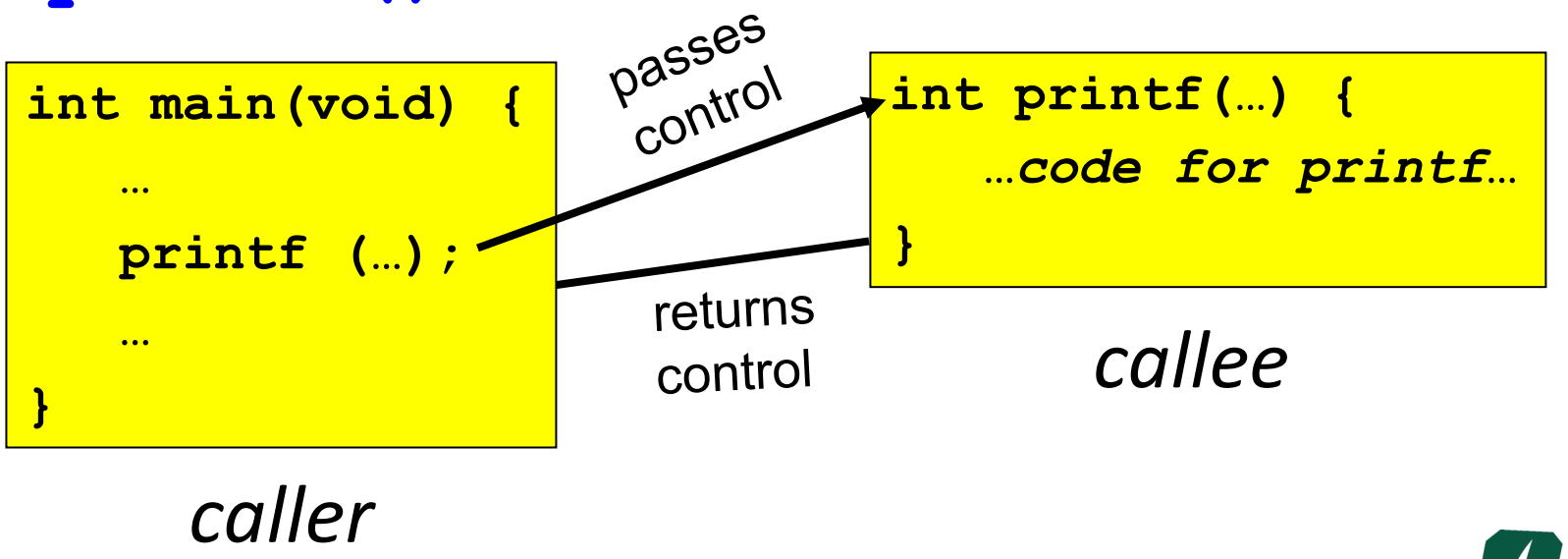
College of Computing and Informatics

Department of Computer Science

Functions in C

- **Functions** are also called *subroutines* or *procedures*
- One part of a program *calls* (or invokes the execution of) the function

Example: **`printf()`**



Are Functions Necessary?

Alternative: just copy the source code of **`printf()`** into the caller, everywhere it is called.

```
int main(void) {
    …
    …code for printing something…
    …
    …code for printing something else…
    …
    …code for printing something else…
    …
}
```

This is called ***inlining*** the function code. Usually **not** the best solution.

Reasons to Use Functions

- Functions **improve modularity**
  - reduce duplication, inconsistency
  - improve readability, easier to understand
  - simplify debugging
    - test parts – unit testing
    - then the whole – system/functional testing
- Allows creation of **libraries** of useful "building blocks" for common processing tasks

Function Return Values

- The **simplest** possible function has no return value and no input parameters. For example:
- Useful?

```
void abort (void)
```

- The next simplest case: value returned, but no input parameters. For example:

```
char getchar (void)
int rand (void)
clock_t clock (void)
```

What Values Can a Function Return?

- The **datatype** of a function can be **any** of:
  - integer or floating point number
  - `struct`s and unions
  - enumerated constants
  - `void`
  - pointers to any of the above (more on this later)
- Each function's type should be **declared before use**

Values… (cont'd)

- **Functions *cannot* return *arrays***, nor can they return **functions**
  - (although they can return **pointers** to both)

```
int main(void) {
    char s[100];
    …
    s[] = readstring();
    …
}

char readstring() [100]  {
     …
}
```


Not legal – do not try!

How Many Values Returned?

- A function can return **at most one value**
- What if you need a function to return **multiple** results?
- Example: you provide the radius and height of a cylinder to a function, and want to get back…

1. surface area

and

2. volume of the cylinder

How Many … (cont'd)

- Choice #1: make the return type a ***struct***

```
typedef struct { //similar to an object
      int area;  // first field
      int vol;   // second field
} mystruct;

mystruct ans;
mystruct cyl (int , int );

int main(void) {
   …
   ans = cyl (r, h);
}
```

How Many … (cont'd)

- Choice **#2**: use ***global* variables**
  - global variables are ***visible*** to (and can be updated by) **all** functions

```
double area, vol;
void cyl (int , int );

int main(void) {
  …
  cyl (r, h);
}
```

```
void cyl (int r, int h)
{
  area = h * (2 * PI * r);
  vol = h * (r * r * PI);
}
```

☠ *common source of bugs* ☠
use of global variables

How Many … (cont'd)

- Choice #3: pass parameters by reference **using pointers**, instead of by value
  - allows them to be updated by the function
- Example: *later, when we talk about pointers…*

Function Side Effects

- Besides the value returned, these are things that *may be* changed by the execution of the function
- Examples
  - input to or output by the computer
  - changes to the state of the computer system
  - changes to global variables
  - changes to input parameters (using pointers)
- There are **problems** with side effects; *we'll come back to this...*

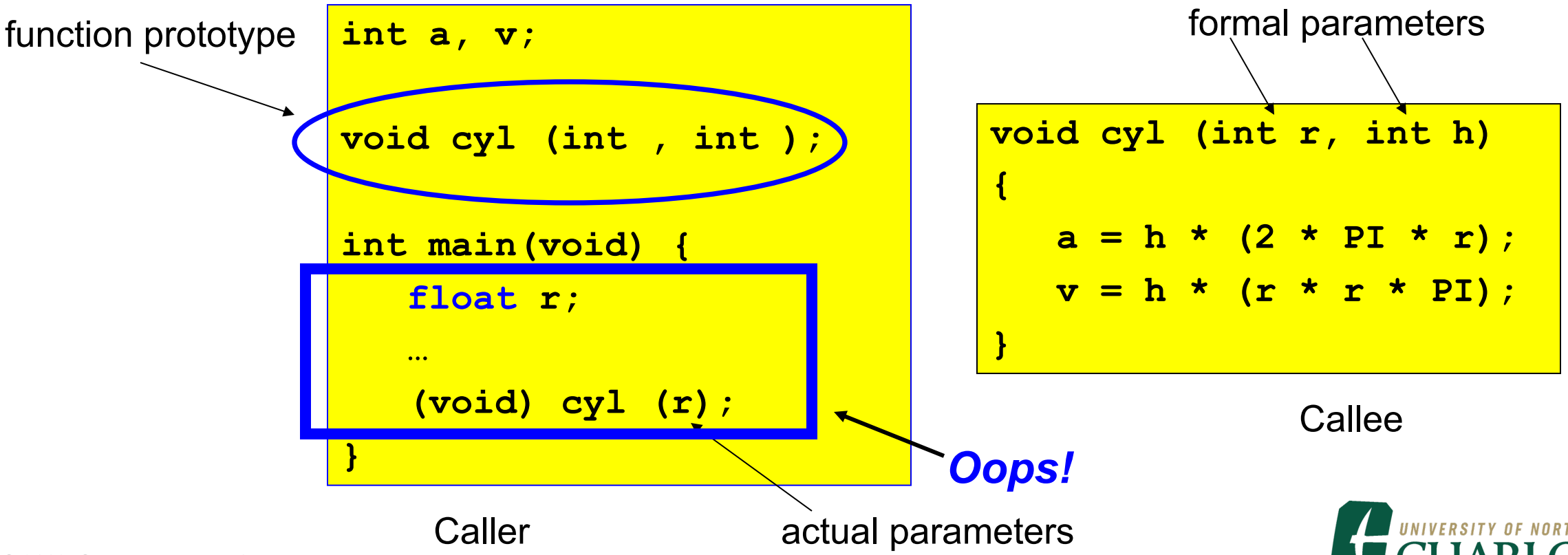
☠ *common source of bugs* ☠
side effects in functions and expressions

Input Parameters of a Function

- Often called ***arguments*** of the function
- Two types
  - ***formal* or *abstract*** – parameter declarations in the function definition
  - ***actual* or *concrete*** – the actual values passed to the function at run time
- If **no** input parameters to the function, leave empty, or use the `void` keyword

Input Parameters of a Function (cont'd)

- The **number and value** of actual parameters should match the number and type of formal parameters



Parameter Passing

- Parameters are passed using ***call-by-value***
  - i.e., a **copy of the parameter value** is made and provided to the function
- Any changes the function makes to this (copied) value have **no effect** on the caller's variables

Input Parameters (cont'd)

Example:

```
float a, v;
void main ( )
{
    int r, h;
    ...
    (void) cylbigger (r, h);
    ...
```

```
void cylbigger (int r, int h)
{
    r = 2 * r;
    h = 2 * h;
    a = h * (2 * PI * r);
    v = h * (r * r * PI);
}
```

does not change caller's variables **r** and **h**

Arrays as Local Variables?

- Arrays can be declared as local variables of functions. For example:

```
int main() {
   double smallarray[20];

   int i, ...
   for (i < 0; i < 20; i++)
      smallarray[i] = ...
```

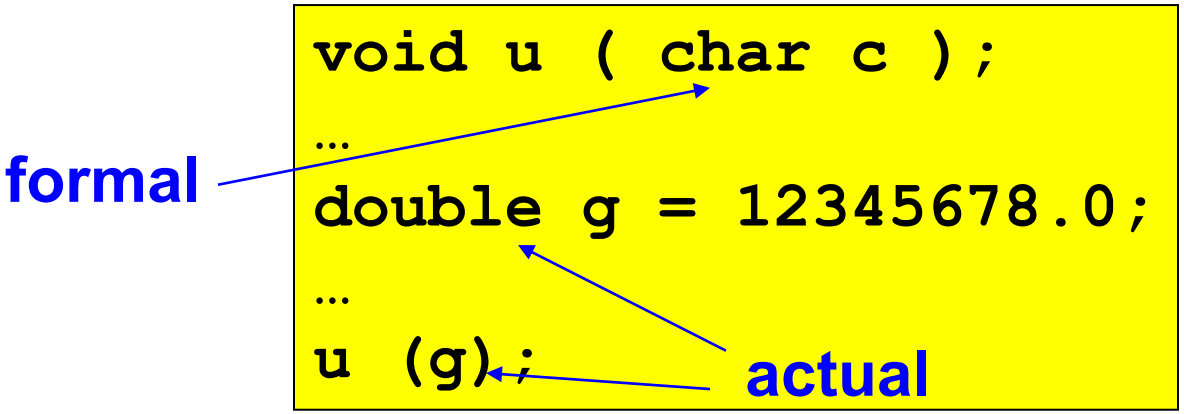
- Space for local variables is allocated on the **stack**
  - **large** arrays **must** be declared as **static** or **global** variables – otherwise segmentation fault occurs

```
double bigarray[10000000];

int main() {
   int i, ...
   for (i = 0; i < 10000000; i++)
      bigarray[i] = ...
```

Types for Function Arguments

In C, an **implicit type conversion** occurs if **actual** argument type is different from **formal** argument type



no compiler warnings!

```
g = 12345678.0
c = 78
```

☠ *common source of bugs* ☠
overlooking type differences in parameters

Advice: more predictable if you cast it yourself

Must Declare Function **Before** Use

Program **with** compilation errors

```
#include <stdio.h>

int main (void)
{
    float w, x, y;
    …
    w = f(x, y);
    …
}

float f (float x, float y)
{
    …
}
```

Program **without** compilation errors

```
#include <stdio.h>

float f (float x, float y)
{
    …
}

int main (void)
{
    float w, x, y;
    …
    w = f(x, y);
    …
}
```

Why should this make a difference?

Declare Before... (cont'd)

- Approaches
  1. (unusual) locate the **function definition** at the beginning of the source code file, or…
  2. **(usual)** put a ***function prototype*** at the beginning of the source code (actual function definition can appear anywhere)

Declare Before... (cont'd)

Program **without** compilation errors

```
#include <stdio.h>

float f (float , float );

int main (void)
{
    float w, x, y;
    …
    w = f(x, y);
    …
}

float f (float x, float y)
{
    …
}
```

← function prototype

Functions and Arrays

Arrays as Function Arguments

- An array can be passed as an **input argument**
- You can specify the array length **explicitly** in the **function declaration**
- Example:

```
void getdays (int months[12])
{
    …
}
```

```
void getdays (int years[10][12])
{
    …
}
```

Arrays as Arguments (cont'd)

- Make **sure** actual argument lengths **agree** with formal argument lengths!
  - will generate compiler errors otherwise
- Example:

```
int years[5][12];
…
result = getdays (years);
```

why not `years[5][12]` here?

Omitting Array Sizes

- **Implicit** length for the **first dimension** of a formal parameter is **allowed**
- However, you **cannot omit** the length of **other dimensions**

OK

```
void days (int years[][12])
{
    …
}
```

NOT OK

```
void days (int years[10][])
{
    …
}
```

Dynamic Array Size Declaration

- Q: How can you tell how big the array is if its size is implicit?
- A: You provide array size as an **input parameter** to the function
- Example:

```
void days (int nm, int months[])
{ … }
```

OR

```
void days (int nm, int months[nm])
{ … }
```

Make sure the size parameter comes **before** the array parameter.

Dynamic Array Size… (cont'd)

```
void days(int ny, int nm, int years[ny][nm])
{   …
    for ( i = 0 ; i < ny ; i++)
        for ( j = 0; j < nm ; j++)
            dcnt += years[i][j];
    …
}
```

Make sure sizes are consistent with array declaration

problem here!

```
int years[10][12];
…
(void) days(20,12, years);
```

☠ *common source of bugs* ☠
mismatches in array size declarations

Arrays as Parameters

- **Arrays are passed BY REFERENCE**, not by value
  - i.e., the **callee** function **can modify** the caller's array values
- Therefore, if you update values in an array passed to a function, you **are** updating the caller's array

```
int years[10][12];
…
(void) changedays(years);
…
void changedays (int inyears[10][12])
{ …   inyears[1][7] = 29;    … }
```

☠ *common source of bugs* ☠
confusion about call by reference vs. call by value

Side Effects, Again

- Q: If a variable is referenced **multiple times** in a single statement, and modified (by side effects) one of those times, do the other references see the side effect?
- Examples:

```
x = 1;
b = --x && x;
```

```
a = 2;
b = ++a;
c = a + a;
```

```
a = 2;
if (a++)
    b = a;
```

```
a = 2;
b = ++a + a;
```

```
a = 2;
b = f( ++a, a);
```

```
a = 2;
b = ++a, c = a;
```

```
a = 2;
x = (++a > 2) ? a : 5;
```

Side Effects… (cont'd)

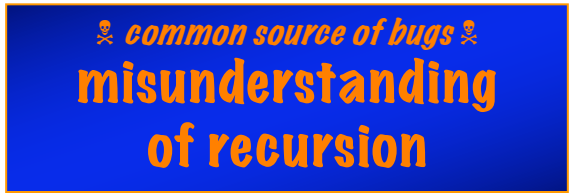
- Complete set of ***sequence points*** for C
  - statement termination `;`
  - closing parenthesis in a condition evaluation `)`
  - the following operators:
    `a&&b` `a||b` `a?b:c` `a,b`
  - **after evaluation** of all arguments to a function call
  - **after returning** a value from a function
- **Advice**: avoid having multiple references to a variable in a single statement if one of those references has side effects.

Functions Calling Functions

- `f()` calls `g()` calls `h()` calls `i()` calls `j()` calls …
- Is there such a thing as having too many layers, or too deep a calling stack? Disadvantages?

Recursion

- What about `f()` calling `f()` ???
- A powerful and flexible way to iteratively compute a value
  - *although this idea seems modest, recursion is one of the most important concepts in computer science*
- Each iteration must temporarily store some input or intermediate values while waiting for the results of recursion to be returned

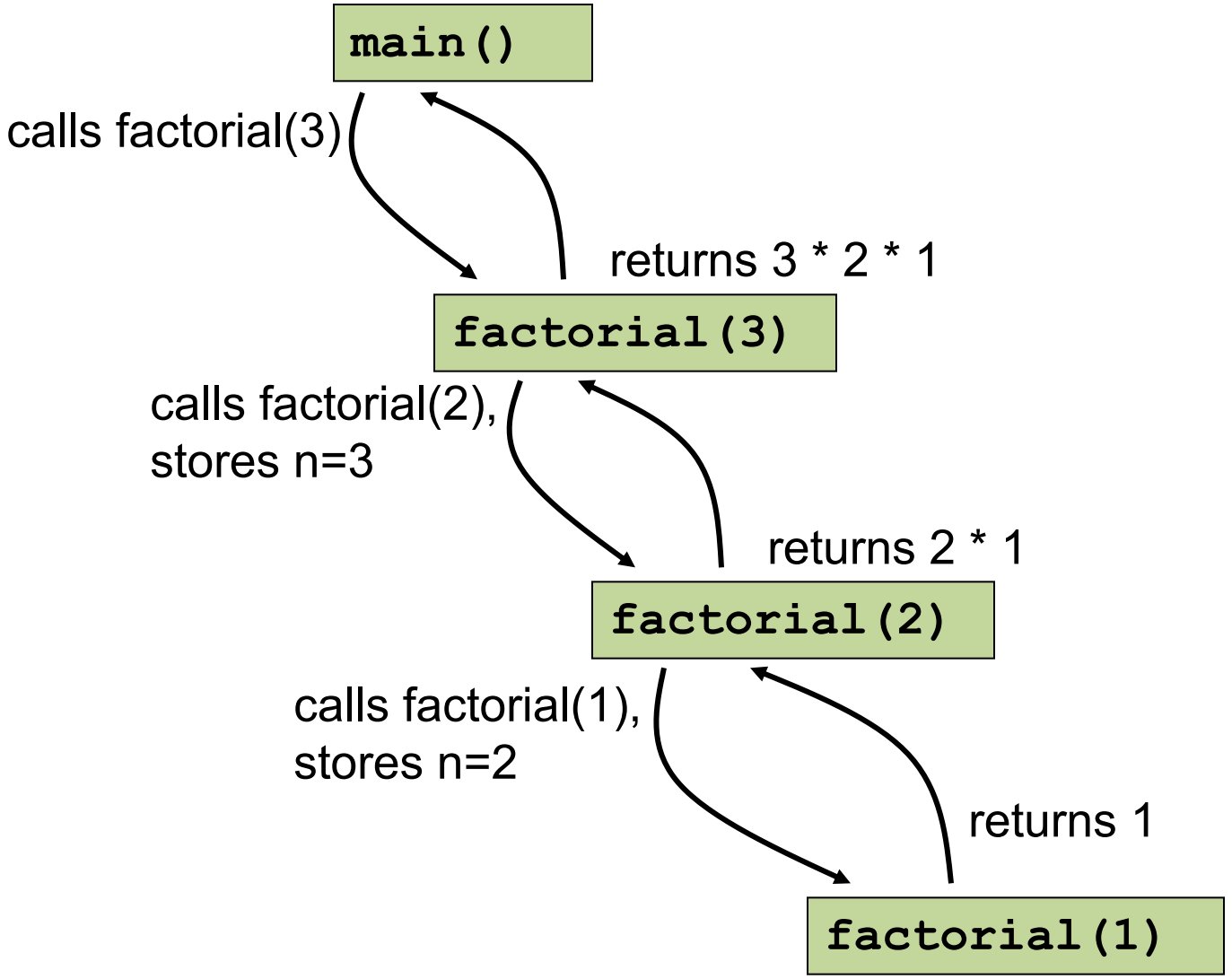


```
...
int main (void)
{ …
   int n = 3;
   w = factorial( n );
…
}

int factorial(int n)
{
   if (n == 1)
      return 1;
   else
      return n * factorial(n-1);
}
```

Recursion Example

Example… (cont'd)



Recursion ... (etc)

- What does the function
  f(*n*) = f(*n*-1) + f(*n*-2) (and f(1) == f(0) == 1) return for n = 5?

```
long long int f (long long int n)
{
  if ((n == 1) || (n == 0))
    return 1;
  else
    return (f(n-1) + f(n-2));
}
```

what function is this? any problems if n = 50?
code it and try!

Recursion or Iteration?

- Every recursion can be **rewritten** as a combination of
  1. a **loop** (iteration), **plus…**
  2. **storage** (a stack) for intermediate values

How Big Should A Function Be?

- **Too small** (100 line program, 20 functions)???
- **Too large** (10,000 line program with 2 functions)???
- Just right ? (Linux recommendations)
  - "Functions should ... do just one thing...[and] fit on one or two screenfuls of text"
  - "... the number of local variables [for a function] .... shouldn't exceed 5-10"

Top-Down Programming in C

- Procedural programming languages encourage a way of structuring your programs:
  - start with the basics
  - then progressively fill in the details
- Ex.: writing a web browser
  - how does one get started on a large program like this?

The C Standard Library

- Small set of useful functions, standardized on all platforms
- Definitions are captured in **24** header files
- Today: how to generate random numbers
  - needed for cryptography, games of chance, simulation, probability, etc…

`<stdlib.h>`: Random Numbers

- The `<stdlib.h>` library header defines:
  - `int rand(void)`
    returns pseudo-random number in range 0 to `RAND_MAX`
  - `void srand(unsigned int seed)`
    uses *seed* to generate new sequence of pseudo-random numbers
  - `RAND_MAX`
    Maximum value returned **`by rand()`**
- Don't forget: `#include <stdlib.h>`

Random Numbers… (cont'd)

- To **seed** the random number generator

```
(void) srand( (unsigned) time (NULL) );
```

where **`time()`** is defined in **`<time.h>`**

- To generate a random (real) number **`r2`** in the (real number) range **`min…max`**:

```
double min = …, max = … ;
double range = max – min;

double r1 =
  ((double) rand() / (double) RAND_MAX) * range;
double r2 = r1 + min;
```

Example

- To **generate a number in the interval [0.0,1.0]**

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

double getrand() {
    int r = rand();
    return ((double) r / (RAND_MAX + 1));
}

int main () {
    (void) srand( time (NULL) );
   …
    double r = getrand();
   …
```

References

- 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.