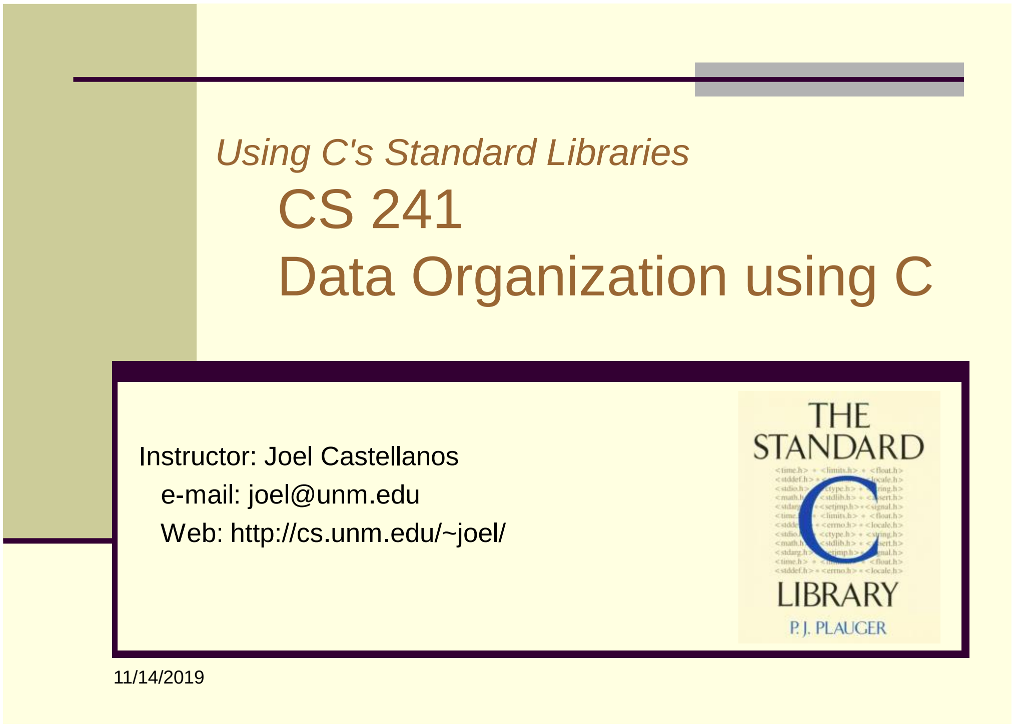

Using C's Standard Libraries

CS 241
Data Organization using C

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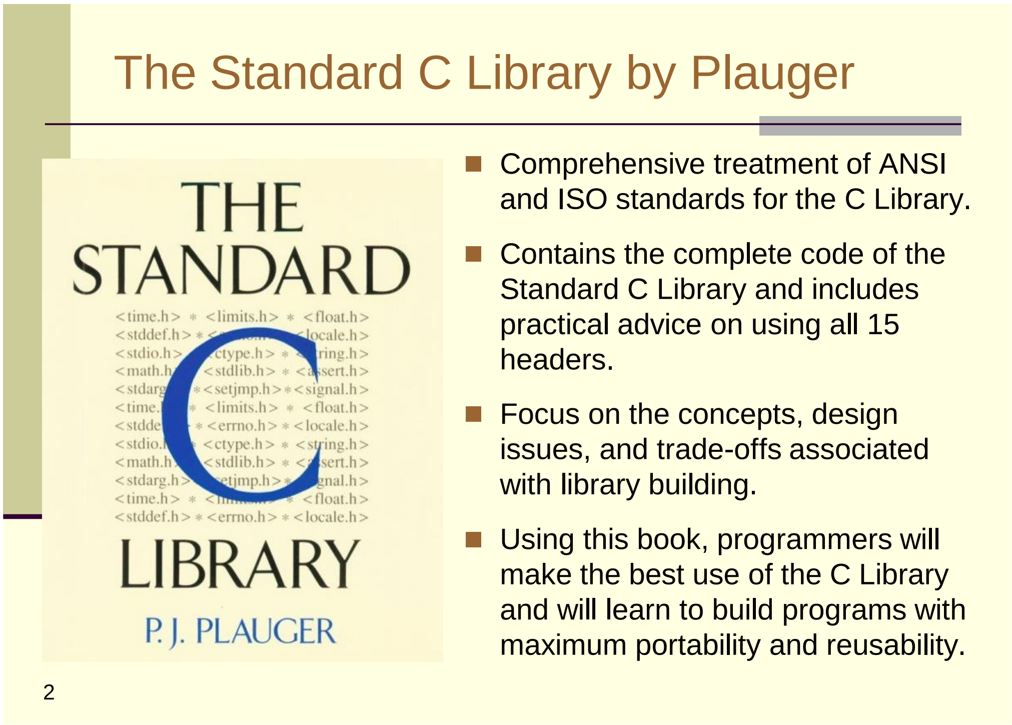
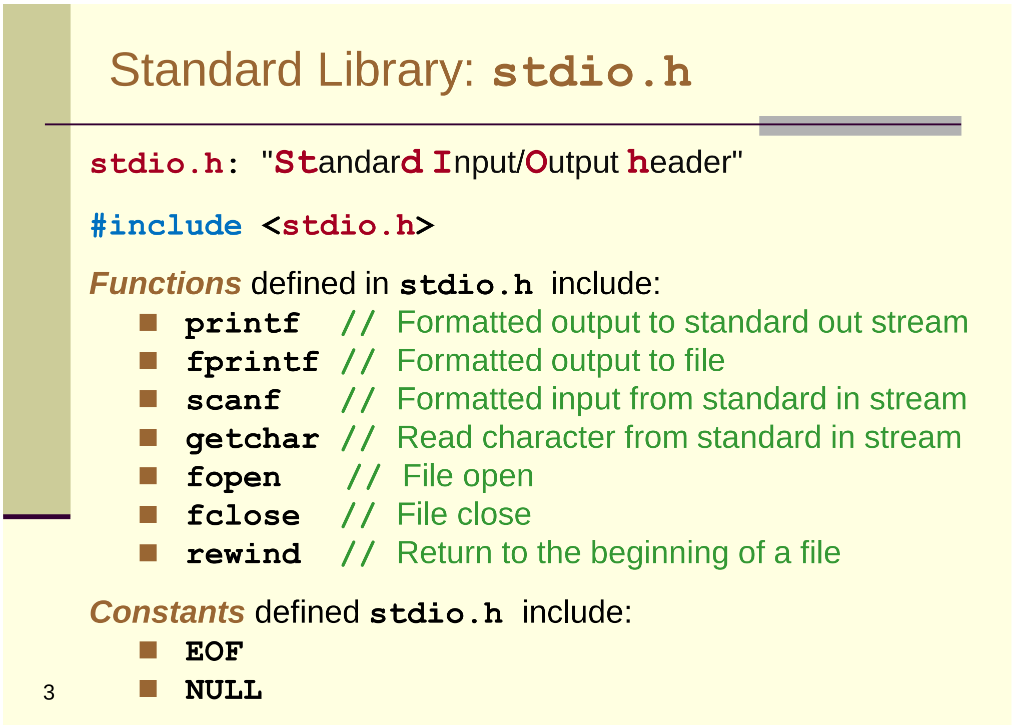


The Standard C Library by Plauger

- Comprehensive treatment of ANSI and ISO standards for the C Library.
- Contains the complete code of the Standard C Library and includes practical advice on using all 15 headers.
- Focus on the concepts, design issues, and trade-offs associated with library building.
- Using this book, programmers will make the best use of the C Library and will learn to build programs with maximum portability and reusability.

THE STANDARD C LIBRARY
<time.h> <limits.h> <float.h> <stddef.h> <locale.h> <stdio.h> <ctype.h> <string.h> <math.h> <stdlib.h> <assert.h> <stdarg.h> <setjmp.h> <signal.h> <errno.h>
P. J. PLAUGER



Standard Library: **`stdio.h`**

`stdio.h`: "**St**andar**d** **I**nput/**O**utput **h**eader"

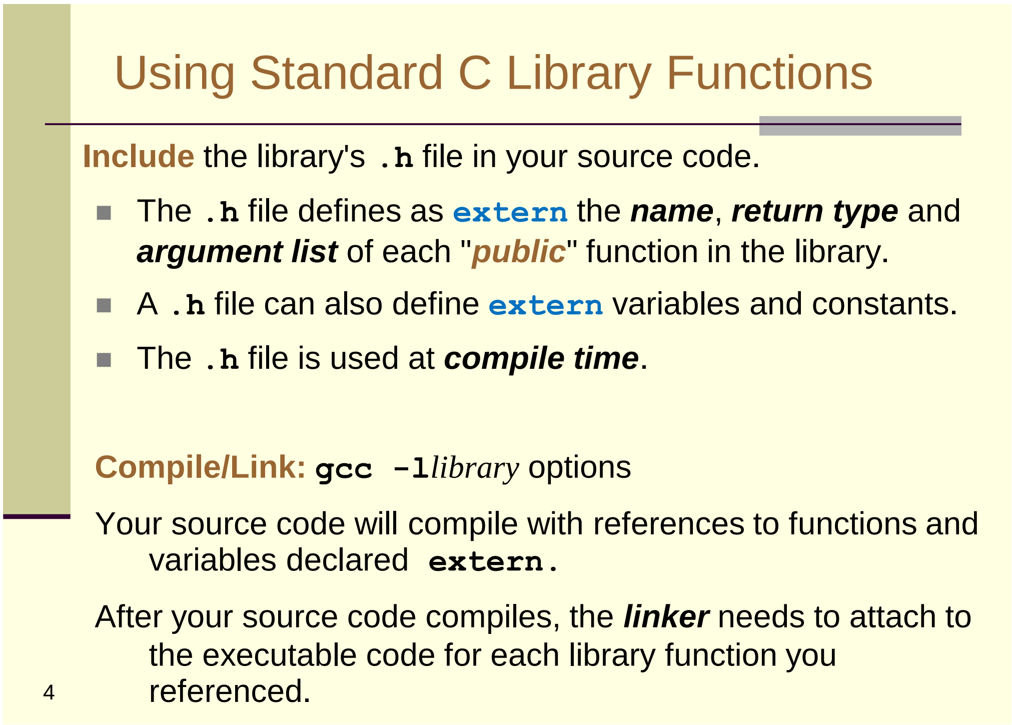
`#include <stdio.h>`

Functions defined in **`stdio.h`** include:

- **`printf`** `//` Formatted output to standard out stream
- **`fprintf`** `//` Formatted output to file
- **`scanf`** `//` Formatted input from standard in stream
- **`getchar`** `//` Read character from standard in stream
- **`fopen`** `//` File open
- **`fclose`** `//` File close
- **`rewind`** `//` Return to the beginning of a file

Constants defined **`stdio.h`** include:

- **`EOF`**
- **`NULL`**



Using Standard C Library Functions

Include the library's **`.h`** file in your source code.

- The **`.h`** file defines as **`extern`** the ***name***, ***return type*** and ***argument list*** of each "***public***" function in the library.
- A **`.h`** file can also define **`extern`** variables and constants.
- The **`.h`** file is used at ***compile time***.

Compile/Link: **`gcc -l`***library* options

Your source code will compile with references to functions and variables declared **`extern.`**

After your source code compiles, the ***linker*** needs to attach to the executable code for each library function you referenced.

gcc -l*library*

- On Unix-like systems, the rule for naming libraries is **lib*x*.a**

  Where *x* is some string.
- Link library **lib*x*.a** with the **gcc** option: **-l*x***.

Example:

- Date and time functions are defined in **time.h.** Thus, to use a time function: **#include <time.h>**
- In C, most library files end with **.a**. The library containing executable code for functions in **time.h** is **libtime.a**
- The **gcc** option for compiling with this library is: **gcc -ltime**

Standard Library: time.h

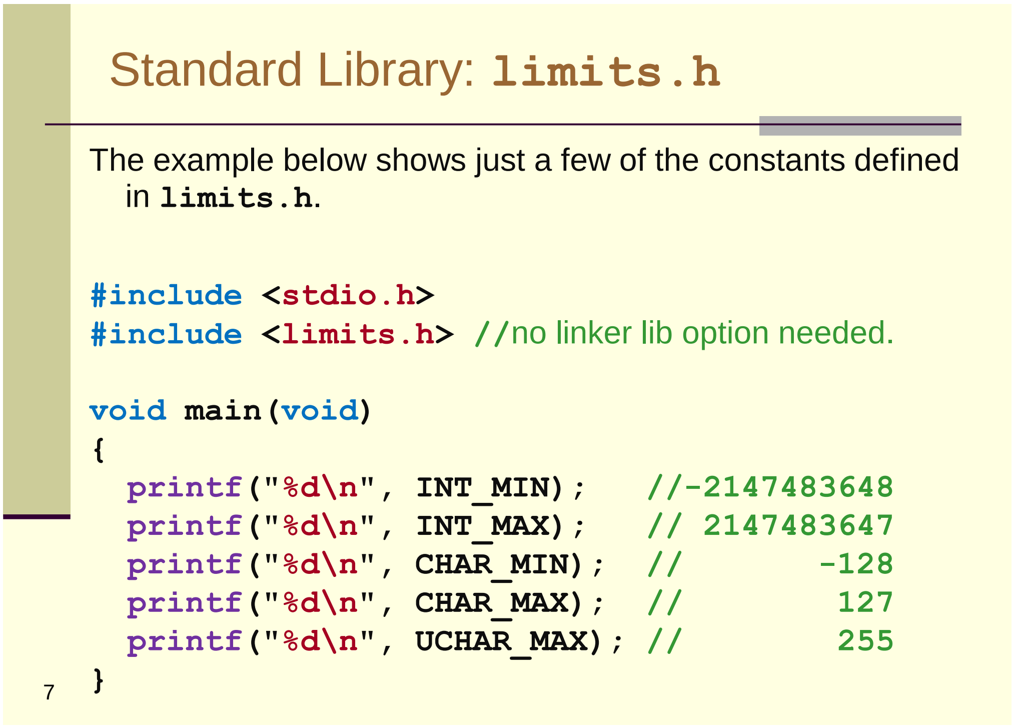
```
#include <stdio.h>
#include <time.h>

void main(void)
{
  time_t clock = time(NULL);


  long sec = (long)clock;
  printf("Seconds since Unix Epoch: %ld\n",sec);

  printf("Current time: %s\n", ctime(&clock));
}
```

On moons, **gcc -ltime** not needed.

Address to copy return value.

On moons.cs.unm.edu, **time_t** is a **long**.

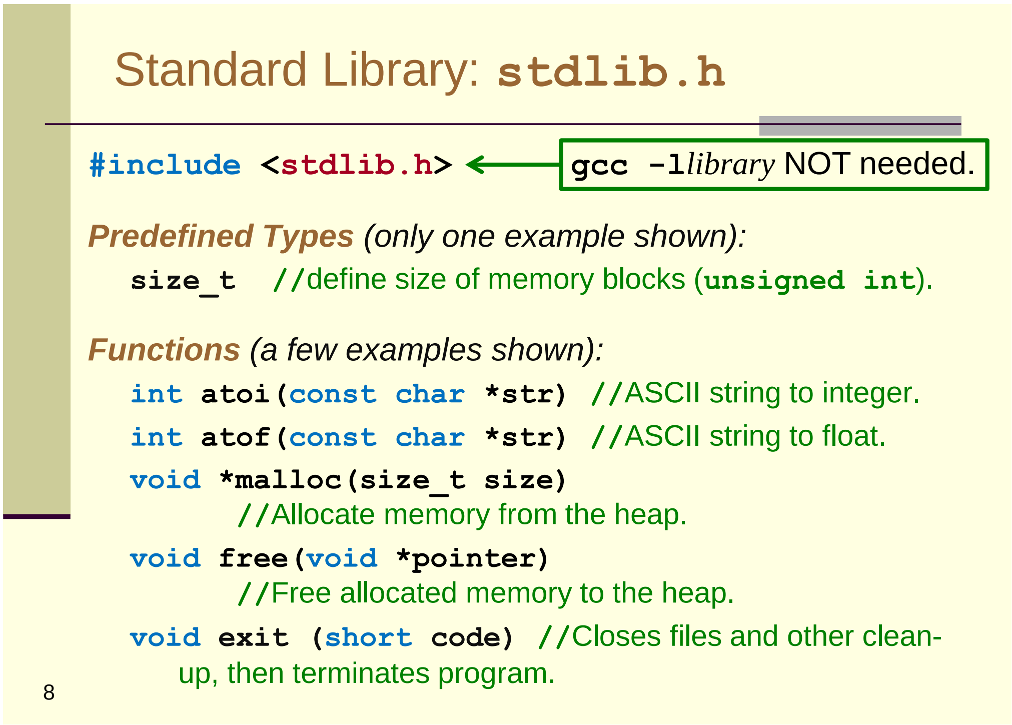
```
Seconds since Unix Epoch: 1332286966
Current time: Tue Mar 20 17:42:46 2012
```



Standard Library: `limits.h`

The example below shows just a few of the constants defined in **`limits.h`**.

```
#include <stdio.h>
#include <limits.h> //no linker lib option needed.

void main(void)
{
  printf("%d\n", INT_MIN);    //-2147483648
  printf("%d\n", INT_MAX);    // 2147483647
  printf("%d\n", CHAR_MIN);   //       -128
  printf("%d\n", CHAR_MAX);   //        127
  printf("%d\n", UCHAR_MAX);  //        255
}
```



Standard Library: `stdlib.h`

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

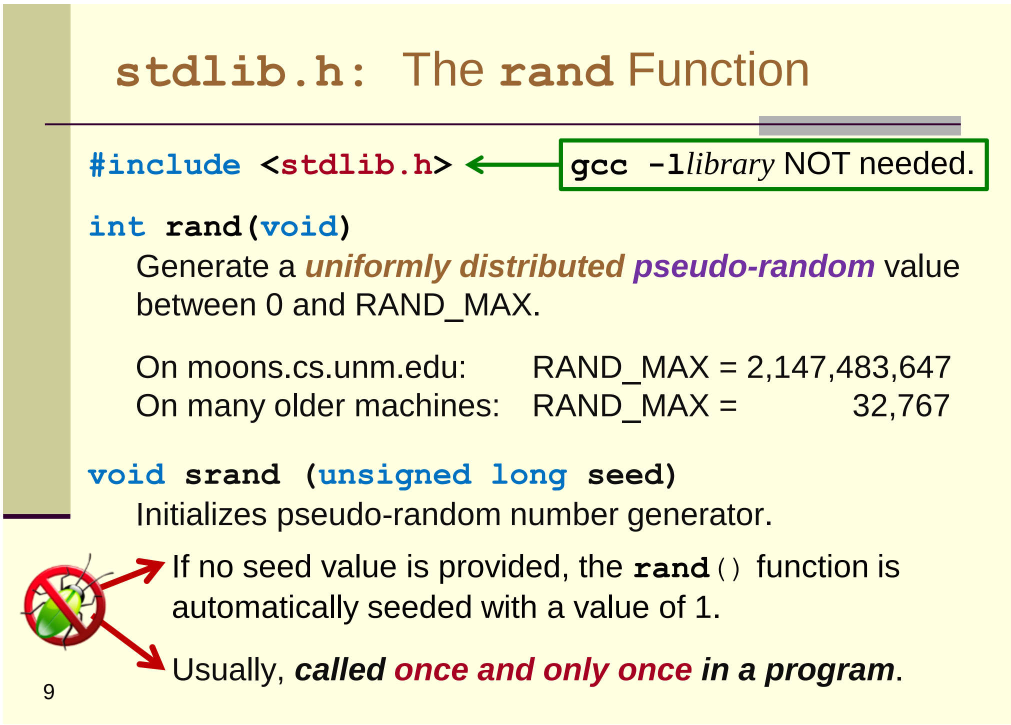
← `gcc -l`*library* NOT needed.

Predefined Types *(only one example shown):*

```
size_t   //define size of memory blocks (unsigned int).
```

Functions *(a few examples shown):*

```
int atoi(const char *str)  //ASCII string to integer.
int atof(const char *str)  //ASCII string to float.
void *malloc(size_t size)
      //Allocate memory from the heap.
void free(void *pointer)
      //Free allocated memory to the heap.
void exit (short code)  //Closes files and other clean-
   up, then terminates program.
```



stdlib.h: The rand Function

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

gcc -l*library* NOT needed.

```
int rand(void)
```

Generate a ***uniformly distributed pseudo-random*** value between 0 and RAND_MAX.

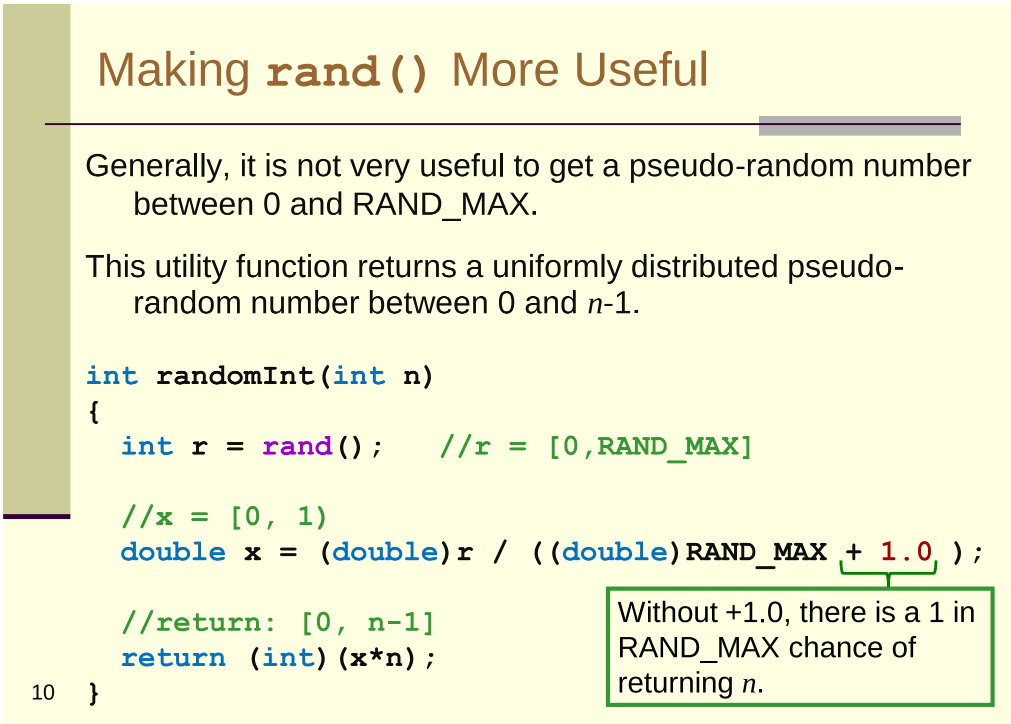
On moons.cs.unm.edu:	RAND_MAX = 2,147,483,647
On many older machines:	RAND_MAX = 32,767

```
void srand (unsigned long seed)
```

Initializes pseudo-random number generator.

If no seed value is provided, the **rand**() function is automatically seeded with a value of 1.

Usually, ***called once and only once in a program***.



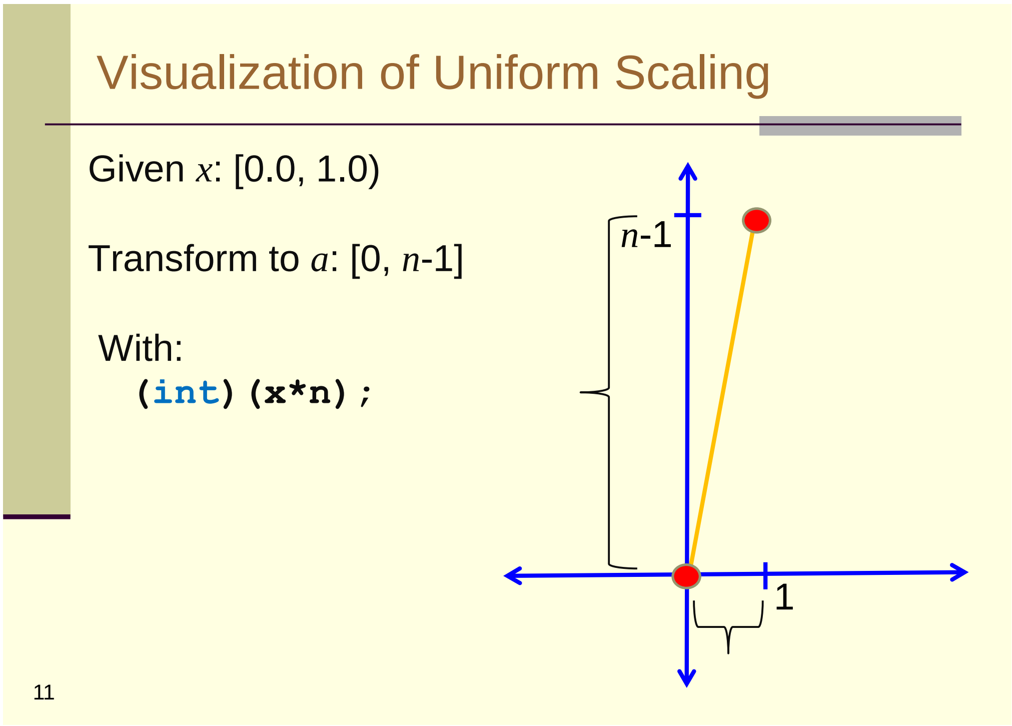
Making rand() More Useful

Generally, it is not very useful to get a pseudo-random number between 0 and RAND_MAX.

This utility function returns a uniformly distributed pseudo-random number between 0 and *n*-1.

```
int randomInt(int n)
{
  int r = rand();   //r = [0,RAND_MAX]

  //x = [0, 1)
  double x = (double)r / ((double)RAND_MAX + 1.0 );

  //return: [0, n-1]
  return (int)(x*n);
}
```

Without +1.0, there is a 1 in RAND_MAX chance of returning *n*.



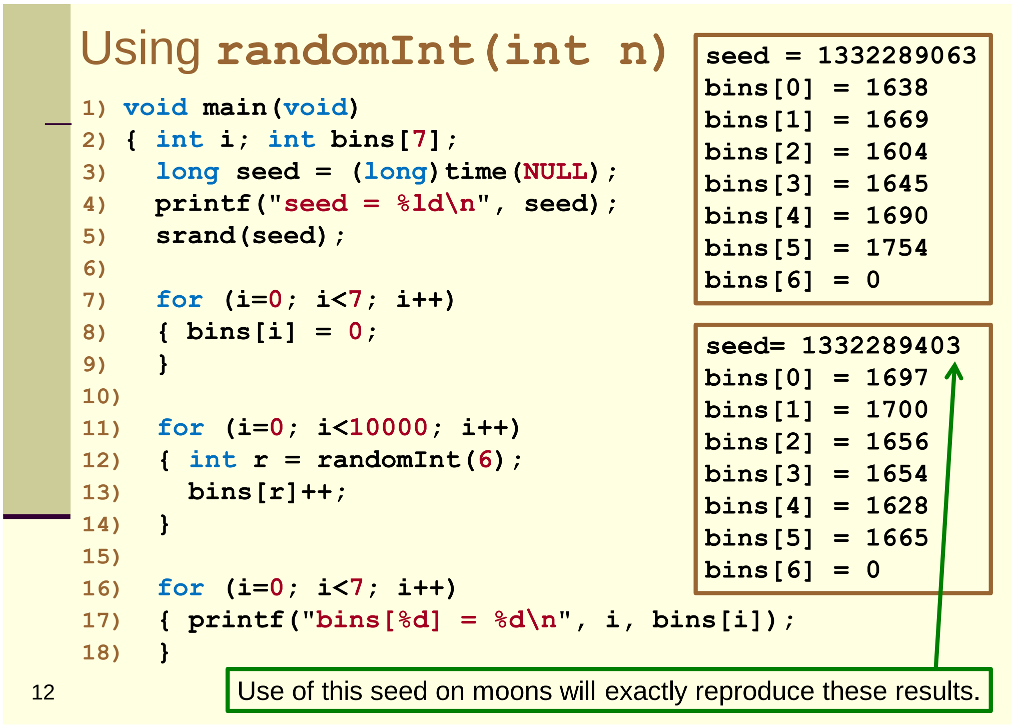
Visualization of Uniform Scaling

Given *x*: [0.0, 1.0)

Transform to *a*: [0, *n*-1]

With:

```
(int)(x*n);
```



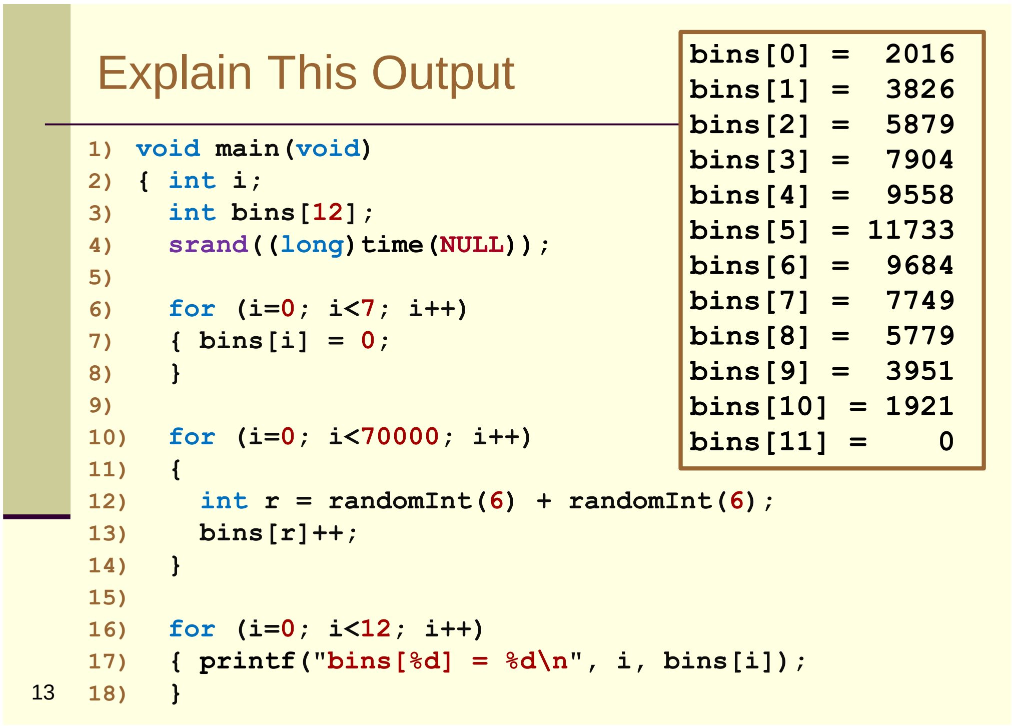
Using `randomInt(int n)`

```
void main(void)
{ int i; int bins[7];
  long seed = (long)time(NULL);
  printf("seed = %ld\n", seed);
  srand(seed);

  for (i=0; i<7; i++)
  { bins[i] = 0;
  }

  for (i=0; i<10000; i++)
  { int r = randomInt(6);
    bins[r]++;
  }

  for (i=0; i<7; i++)
  { printf("bins[%d] = %d\n", i, bins[i]);
  }
```

```
seed = 1332289063
bins[0] = 1638
bins[1] = 1669
bins[2] = 1604
bins[3] = 1645
bins[4] = 1690
bins[5] = 1754
bins[6] = 0
```

```
seed= 1332289403
bins[0] = 1697
bins[1] = 1700
bins[2] = 1656
bins[3] = 1654
bins[4] = 1628
bins[5] = 1665
bins[6] = 0
```

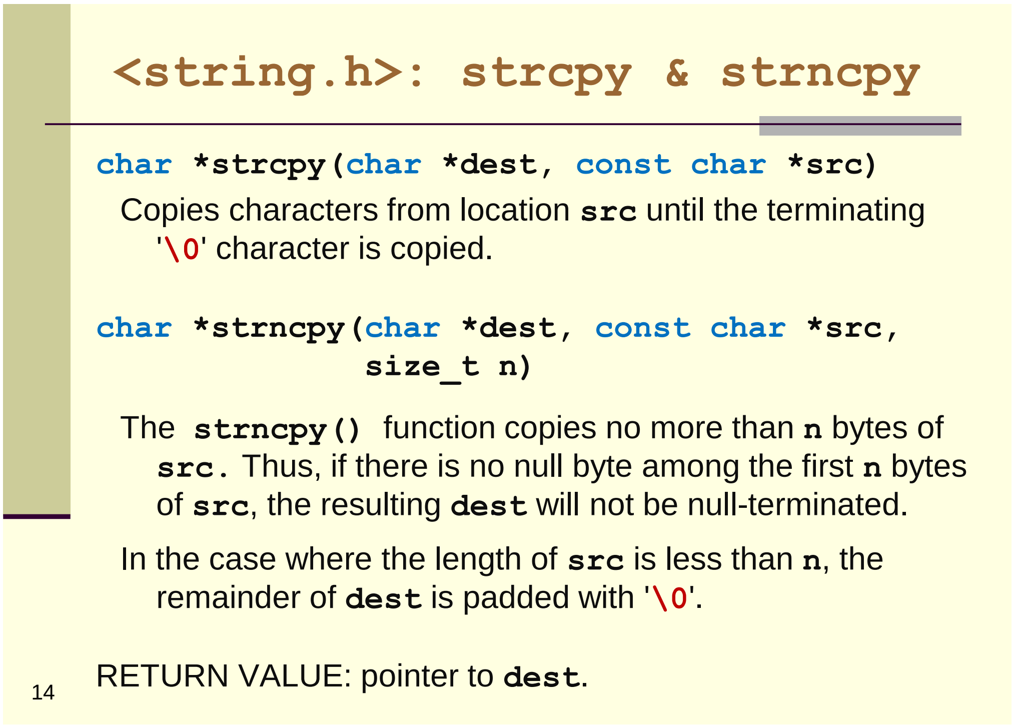
Use of this seed on moons will exactly reproduce these results.



Explain This Output

```
bins[0] =  2016
bins[1] =  3826
bins[2] =  5879
bins[3] =  7904
bins[4] =  9558
bins[5] = 11733
bins[6] =  9684
bins[7] =  7749
bins[8] =  5779
bins[9] =  3951
bins[10] = 1921
bins[11] =    0
```

```
void main(void)
{ int i;
  int bins[12];
  srand((long)time(NULL));

  for (i=0; i<7; i++)
  { bins[i] = 0;
  }

  for (i=0; i<70000; i++)
  {
    int r = randomInt(6) + randomInt(6);
    bins[r]++;
  }

  for (i=0; i<12; i++)
  { printf("bins[%d] = %d\n", i, bins[i]);
  }
```



<string.h>: strcpy & strncpy

`char *strcpy(char *dest, const char *src)`

Copies characters from location **src** until the terminating '\0' character is copied.

```
char *strncpy(char *dest, const char *src,
              size_t n)
```

The **strncpy()** function copies no more than **n** bytes of **src.** Thus, if there is no null byte among the first **n** bytes of **src**, the resulting **dest** will not be null-terminated.

In the case where the length of **src** is less than **n**, the remainder of **dest** is padded with '\0'.

RETURN VALUE: pointer to **dest**.

<string.h>: strlen

`int strlen(const char* str)`

Returns the number of bytes in the string to which **`str`** points, not including the terminating NULL byte.

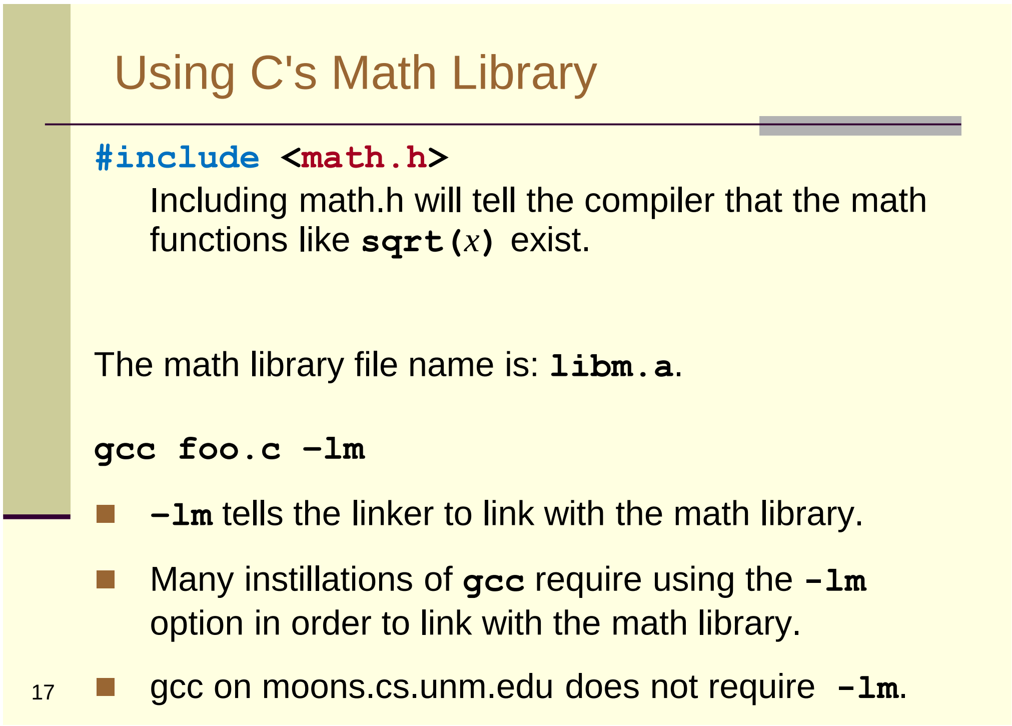
```
#include <stdio.h>
int strlen(const char str[])
{ int i=0;
  while (str[i]) i++;
  return i;
}

void main(void)
{ char word[] = "Hello";
  printf("%d\n", strlen(word));
}
```

Ok to return an automatic variable because it is return by value.

Standard Library: **math.h**

```
double pow(double x, double y)//x raised to power y.
double log(double x)    // Natural logarithm of x.
double log10(double x)  //  Base 10 logarithm of x.
double sqrt(double x)  //  Square root of x.
double ceil(double x)//Smallest integer not < x.
double floor(double x)//Largest integer not > x.
double sin(double x)  //  sin of x in radians.
int abs(int n)  //  absolute value of n.
long labs(long n)  //  absolute value of n.
double fabs(double x)  //  absolute value of x.
```

Carful not to use **`abs`** when you want **`fabs`**.



Using C's Math Library

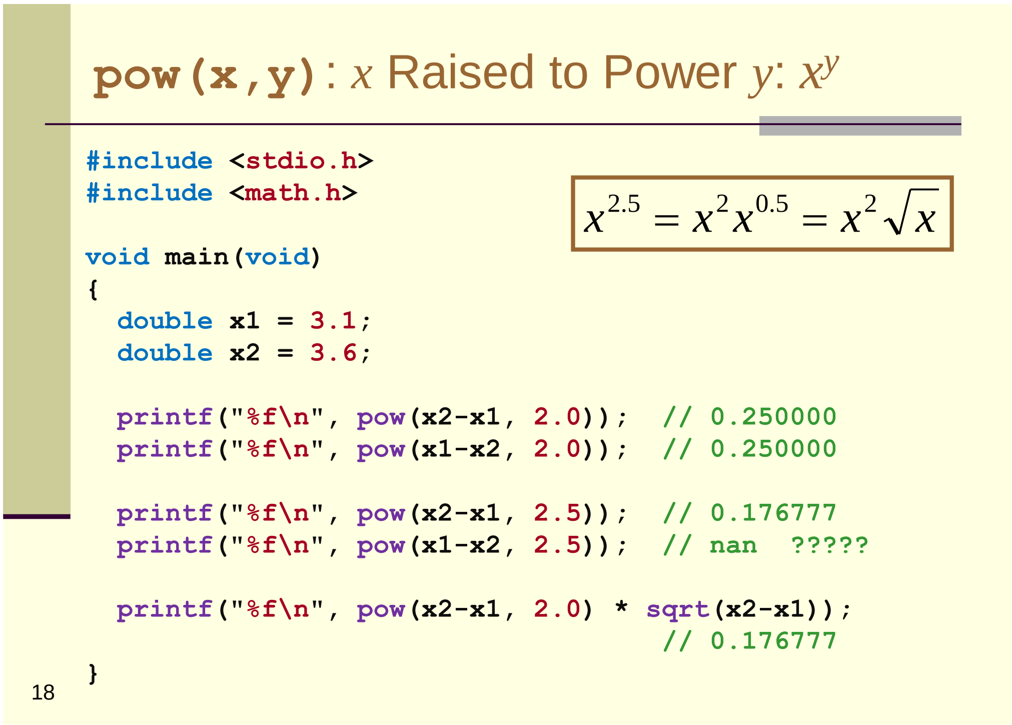
#include <math.h>

Including math.h will tell the compiler that the math functions like **sqrt(*x*)** exist.

The math library file name is: **libm.a**.

```
gcc foo.c -lm
```

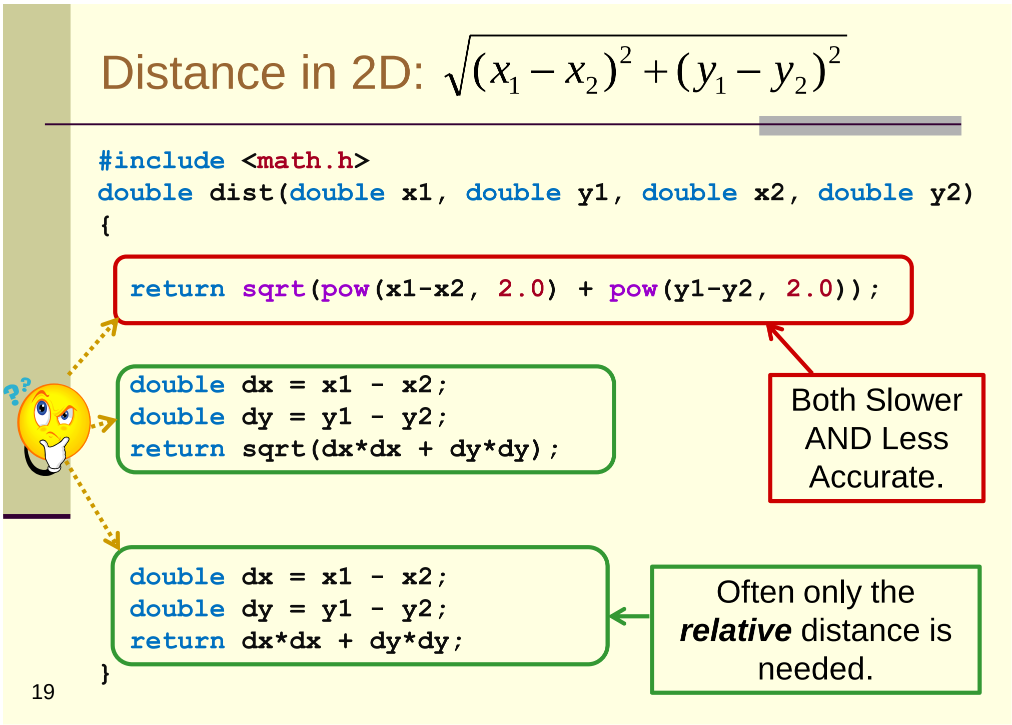
- **-lm** tells the linker to link with the math library.
- Many instillations of **gcc** require using the **-lm** option in order to link with the math library.
- gcc on moons.cs.unm.edu does not require **-lm**.



pow(x,y): *x* Raised to Power *y*: x^y

$$\boxed{x^{2.5} = x^2 x^{0.5} = x^2\sqrt{x}}$$

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

void main(void)
{
  double x1 = 3.1;
  double x2 = 3.6;

  printf("%f\n", pow(x2-x1, 2.0));  // 0.250000
  printf("%f\n", pow(x1-x2, 2.0));  // 0.250000

  printf("%f\n", pow(x2-x1, 2.5));  // 0.176777
  printf("%f\n", pow(x1-x2, 2.5));  // nan  ?????

  printf("%f\n", pow(x2-x1, 2.0) * sqrt(x2-x1));
                                    // 0.176777
}
```



Distance in 2D: $\sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}$

```
#include <math.h>
double dist(double x1, double y1, double x2, double y2)
{
```

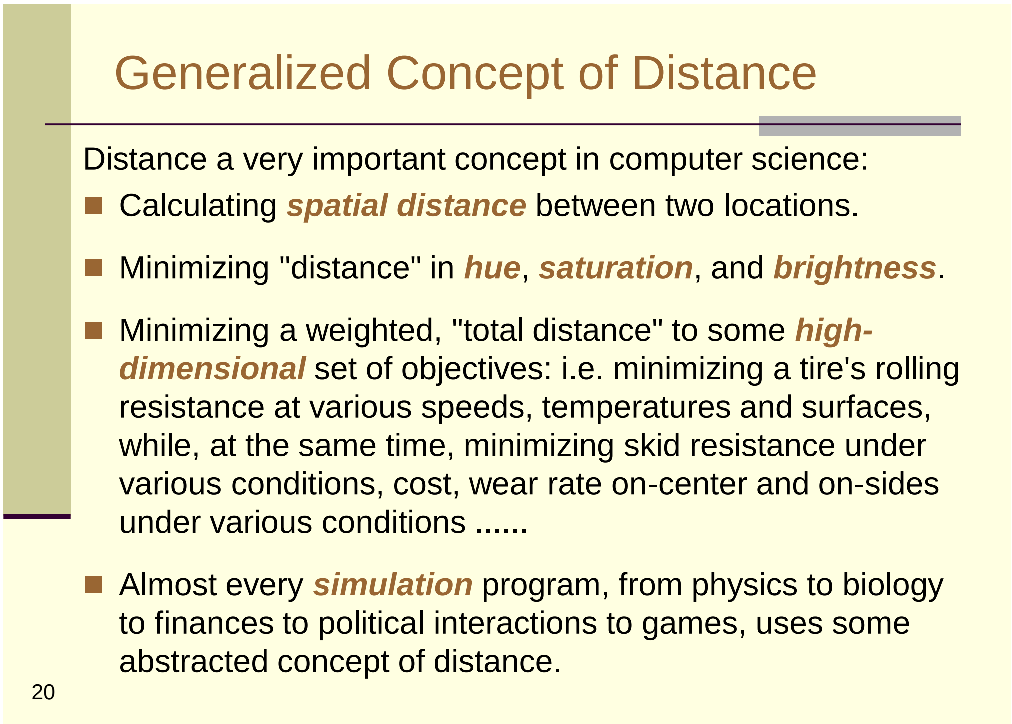
```
  return sqrt(pow(x1-x2, 2.0) + pow(y1-y2, 2.0));
```

Both Slower AND Less Accurate.

```
  double dx = x1 - x2;
  double dy = y1 - y2;
  return sqrt(dx*dx + dy*dy);
```

```
  double dx = x1 - x2;
  double dy = y1 - y2;
  return dx*dx + dy*dy;
}
```

Often only the ***relative*** distance is needed.



Generalized Concept of Distance

Distance a very important concept in computer science:

- Calculating ***spatial distance*** between two locations.
- Minimizing "distance" in ***hue***, ***saturation***, and ***brightness***.
- Minimizing a weighted, "total distance" to some ***high-dimensional*** set of objectives: i.e. minimizing a tire's rolling resistance at various speeds, temperatures and surfaces, while, at the same time, minimizing skid resistance under various conditions, cost, wear rate on-center and on-sides under various conditions ......
- Almost every ***simulation*** program, from physics to biology to finances to political interactions to games, uses some abstracted concept of distance.