Announcements

• Lab 2 – Due Friday
• HW 1 – Due Thursday
A Few Odds and Ends

• Comments
  – Anywhere in the code
  – C-Style => “/*” and “*/”
  – C++ Style => “//”

• Variable
  – When declared they will have "garbage" (random or unknown) values unless you initialize them
  – Each variable must be initialized separately

• Scope
  – Global variables are visible to all the code/functions in the program and are declared outside of any function
  – Local variables are declared inside of a function and are only visible in that function and die when the function ends

```cpp
/* Anything between slash-star and star-slash is ignored even across multiple lines of text or code */
/*----Section 1: Compiler Directives ----*/
#include <iostream>
#include <cmath>
using namespace std;

// Global Variables
int x; // Anything after "//" is ignored

int add_1 (int input)
{
    return (input + 1);
}

int main(int argc, char *argv[])
{
    // y and z are "local" variables
    int y, z=5; // y is garbage, z is five
    z = add_1(z);
    y = z+1; // an assignment stmt
    cout << y << endl;
    return 0;
}
```
Function call statements

- C++ predefines a variety of functions for you. Here are a few of them:
  - `sqrt(x)`: returns the square root of `x` (in `<cmath>`)
  - `pow(x, y)`: returns $x^y$, or `x` to the power `y` (in `<cmath>`)
  - `sin(x)`: returns the sine of `x` if `x` is in radians (in `<cmath>`)
  - `abs(x)`: returns the absolute value of `x` (in `<cstdlib>`)
  - `max(x, y)`: returns the maximum of `x` and `y` (in `<algorithm>`)
  - `min(x, y)`: returns the maximum of `x` and `y` (in `<algorithm>`)

- You call these by writing them similarly to how you would use a function in mathematics:

```cpp
#include <iostream>
#include <cmath>
#include <algorithm>
using namespace std;

int main(int argc, char *argv[]) {
    // can call functions
    // in an assignment
    double res = cos(0);

    // can call functions in an expression
    res = sqrt(2) + 2.3 << endl;

    // can call them as part of a output statement
    cout << max(34, 56) << endl;

    return 0;
}
```
Review

• Write a program to ask the user to enter two integers representing hours then minutes. Output the equivalent number of seconds.

• To get started...
  – Go to http://cs103.usc.edu/websheets/index.php#seconds
  – We've started the program for you...look at the
    • General template for a program with the #includes, using namespace std; and int main() function which returns 0
  – We've declared variables where you can store the input and computation results
  – Now you add code to
    • Get input from the user
    • And compute the answer and place it in the 'sec' variable
CONTROL STRUCTURES
Comparison/Logical Operators

• Loops & conditional statements require a condition to be evaluated resulting in a True or False determination.

• In C/C++...
  – 0 means False
  – Non-Zero means True
  – bool type available in C++ => ‘true’ and ‘false’ keywords can be used but internally ‘true’ = 1 and ‘false’ = 0

• Example 1
  int x = 100;
  while(x)
  { x--;}

• Usually conditions results from comparisons
  ==, !=, >, <, >=, <=
Logical AND, OR, NOT

- Often want to combine several conditions to make a decision
- Logical AND => \( \text{expr}_a \&\& \text{expr}_b \)
- Logical OR => \( \text{expr}_a \mid\mid \text{expr}_b \)
- Logical NOT => \( ! \text{expr}_a \)
- Precedence (order of ops.) => \( !\) then \&\& then \mid\mid
  - \( !x \mid\mid y\&\&!z \)
  - \( ((!x)\mid\mid(y\&\&(!z))) \) ... if \( x=100, y=-3, z=0 \) then this expression is...
- Write a condition that eats a sandwich if it has neither tomato nor lettuce
  - if ( \(!\text{tomato} \&\& \!\text{lettuce}) \) \{ \text{eat_sandwich}(); \}
  - if ( \((\!\text{tomato} \mid\mid \text{lettuce}))\) \{ \text{eat_sandwich}(); \}

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Exercise

• Which of the following is NOT a condition to check if the integer x is in the range [-1 to 5]
  – x >= -1 && x <= 5
  – -1 <= x <= 5
  – ! ( x < -1 || x > 5)
  – x > -2 && x < 6

• Consider ( ( !x ) || ( y && ( !z ) ) )
If x=100, y= -3, z=0 then this expression is...
  – true
  – false
If...Else If...Else

- Use to execute only certain portions of code
- Else If is *optional*
  – Can have any number of else if statements
- Else is *optional*
- { ... } indicate code associated with the if, else if, else block

```java
if (condition1)
{
    // executed if condition1 is True
}
else if (condition2)
{
    // executed if condition2 is True
    // but condition1 was False
}
else if (condition3)
{
    // executed if condition3 is True
    // but condition1 and condition2
    // were False
}
else
{
    // executed if neither condition
    // above is True
}
```
if (condition1)
{
    // executed if condition1 is True
}
else
{
    // executed if neither condition
    // above is True
}

// following statements
if (condition1)
{
    // executed if condition1 is True
}
else if (condition2)
{
    // executed if condition2 is True
    // but condition1 was False
}
else
{
    // executed if neither condition
    // above is True
}
// following statements

Flow Chart

If Block Statements

Else If Statements

Else Statements

Following statements
Exercises

• Discount
  – http://cs103.usc.edu/websheets/index.php#discount

• Weekday
  – http://cs103.usc.edu/websheets/index.php#weekday

• N-th
  – http://cs103.usc.edu/websheets/index.php#nth
The Right Style

- Is there a difference between the following two code snippets?
- Both are equivalent but the bottom is preferred because it makes clear to other programmers that only one or the other case will execute.

```cpp
int x;
cin >> x;
if( x >= 0 ) { cout << "Positive"; }
if( x < 0  ) { cout << "Negative"; }
```

```cpp
int x;
 cin >> x;
if( x >= 0 ) { cout << "Positive"; }
else { cout << "Negative"; }
```
Find the bug

- What's the problem in this code...

```cpp
// What’s the problem below
int x;
cin >> x;
if (x == 1)
    { cout << "X is 1" << endl; }
else
    { cout << "X is not 1" << endl; } 
```
Find the bug

- Common mistake is to use assignment '==' rather than equality comparison '==' operator
- Assignment puts 1 into x and then uses that value of x as the "condition"
  - 1 = true so we will always execute the if portion

```cpp
// What’s the problem below
int x;
cin >> x;
if (x == 1)
    { cout << "X is 1" << endl; }
else
    { cout << "X is not 1" << endl; }
```
Switch (Study on own)

- Again used to execute only certain blocks of code
- Best used to select an action when an expression could be 1 of a set of values
- `{ ... }` around entire set of cases and not individual case
- Computer will execute code until a break statement is encountered
  - Allows multiple cases to be combined
- Default statement is like an else statement

```java
switch(expr) // expr must eval to an int
{
    case 0:
        // code executed when expr == 0
        break;
    case 1:
        // code executed when expr == 1
        break;
    case 2:
    case 3:
    case 4:
        // code executed when expr is 2, 3, or 4
        break;
    default:
        // code executed when no other case is executed
        break;
}
```
Switch (Study on own)

• What if a break is forgotten?
  – All code underneath will be executed until another break is encountered

```java
switch(expr) // expr must eval to an int
{
    case 0:
        // code executed when expr == 0
        break;
    case 1:
        // code executed when expr == 1
        // what if break was commented
        // break;
    case 2:
    case 3:
    case 4:
        // code executed when expr is
        // 3, 4 or 5
        break;
    default:
        // code executed when no other
        // case is executed
        break;
}
```
Performing repetitive operations

LOOPS
Need for Repetition

- We often want to repeat a task but do so in a concise way
  - Print out all numbers 1-100
  - Keep taking turns until a game is over
    - Imagine the game of 'war'...it never ends!!
- We could achieve these without loops, but...

```cpp
#include <iostream>
using namespace std;

int main()
{
    cout << 1 << endl;
    cout << 2 << endl;
    ...
    cout << 100 << endl;
    return 0;
}
```

```cpp
#include <iostream>
using namespace std;

int main()
{
    bool gameOver;
    gameOver = take_turn();
    if( ! gameOver ){
        gameOver = take_turn();
        if( ! gameOver ) {
            ...
            }
    }
}
```
while Loop

• While
  – Cond is evaluated first
  – Body only executed if cond. is true (maybe 0 times)

• Do..while
  – Body is executed at least once
  – Cond is evaluated
  – Body is repeated if cond is true

• Rule of thumb: Use when number of iterations is determined by a condition updating inside the loop body

```
// While Type 1:
while (condition)
{
    // code to be repeated
    // (should update condition)
}

// While Type 2:
do {
    // code to be repeated
    // (should update condition)
} while(condition);
```
while Loop

- One way to think of a while loop is as a repeating 'if' statement
- When you describe a problem/solution you use the words 'until some condition is true' that is the same as saying 'while some condition is not true'

```c++
// guessing game
bool guessedCorrect = false;
if( !guessed )
{
    guessedCorrect = guessAgain();
} // want to repeat if cond. check again
```

An if-statement will only execute once

```c++
// guessing game
bool guessedCorrect = false;
while( !guessed )
{
    guessedCorrect = guessAgain();
}
```

A 'while' loop acts as a repeating 'if' statement
While Loop Exercise

- http://cs103.usc.edu/websheets/index.php#countodd
Finding the ‘while’ Structure

Loop Flow Chart for Guessing Game

Accept Guess

No

Correct

Yes

Post-Loop Code

Accept Guess

Incorrect

Yes

Accept Guess

No

Accept Guess

Post-Loop Code

Here we check at the end to see if we should repeat...perfect for a do..while loop

do
{ body }
while (cond)

But a while loop checks at the beginning of the loop, so we must accept one guess before starting:

while( cond )
{ body }

"Unroll“ (show more iterations of) the loop and re-organize

Accept Guess

Correct

No

Accept Guess

Correct

Yes

Post-Loop Code
for Loop

- Init stmt executed first
- Cond is evaluated next
- Body only executed if cond. is true
- Update stmt executed
- Cond is re-evaluated and execution continues until it is false
- Multiple statements can be in the init and update statements
- Rule of thumb: Use when number of iterations is independent of loop body

```c++
for(init stmt; cond; update stmt)
{
    // body of loop
}
```

// Outputs 0 5 10 15 ... 95
```c++
for(i=0; i < 100; i++){
    if(i % 5 == 0){
        cout << i << " is a multiple of 5";
        cout << endl;
    }
}
```

```c++
for(i=0; i < 20; i++){
    cout << 5*i << " is a multiple of 5";
    cout << endl;
}
```

// compound init and update stmts.
```c++
for(i=0, j=0; i < 20; i++, j+=5){
    cout << j << " is a multiple of 5";
    cout << endl;
}
```
for Loop

- Convert the following for loops to equivalent while loop structures

```c
for(init stmt; cond; update stmt)
{
    // body of loop
}

// Equivalent while structure
```
Loop Practice

• Write a for loop to compute the first 10 terms of the Liebniz approximation of $\pi/4$:
  
  $\pi/4 = 1/1 - 1/3 + 1/5 - 1/7 + 1/9 \ldots$
  
  • Tip: write a table of the loop counter variable vs. desired value and then derive the general formula
  
  • [http://cs103.usc.edu/websheets/index.php?#liebnizapprox](http://cs103.usc.edu/websheets/index.php?#liebnizapprox)

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</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>+1/1</td>
<td>for(i=0;i&lt;10;i++) Fraction:</td>
<td>1</td>
<td>+1/1</td>
<td>for(i=1; i&lt;=19; i+=2) Fraction:</td>
</tr>
<tr>
<td>1</td>
<td>-1/3</td>
<td></td>
<td>3</td>
<td>-1/3</td>
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<tr>
<td>2</td>
<td>+1/5</td>
<td>+/- =&gt;</td>
<td>5</td>
<td>+1/5</td>
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<td>-1/19</td>
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Loop Practice

• Write a for loop to compute the first 10 terms of the Liebniz approximation of $\pi/4$:
  
  • $\pi/4 = 1/1 – 1/3 + 1/5 – 1/7 + 1/9 …$

  • Tip: write a table of the loop counter variable vs. desired value and then derive the general formula

• [http://cs103.usc.edu/websheets/index.php?#liebnizapprox](http://cs103.usc.edu/websheets/index.php?#liebnizapprox)

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<td>for(i=0; i&lt;10; i++)</td>
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</tr>
<tr>
<td>1</td>
<td>-1/3</td>
<td>Fraction: 1/(2*i+1)</td>
<td>3</td>
<td>-1/3</td>
<td>Fraction: 1/i</td>
</tr>
<tr>
<td>2</td>
<td>+1/5</td>
<td>+/- =&gt; pow(-1,i) if(i is odd) neg.</td>
<td>5</td>
<td>+1/5</td>
<td></td>
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<td>...</td>
<td>...</td>
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Loop Practice

• Write for loops to compute the first 10 terms of the following approximations:
  – $e^x$: $1 + x + \frac{x^2}{2!} + \frac{x^3}{3!} + \frac{x^4}{4!} \ldots$
    • Assume 1 is the 1st term and assume functions
      – fact(int n) // returns n!
      – pow(double x, double n) // returns $x^n$
  – Wallis:
    • $\pi/2 = \frac{2}{1} \times \frac{2}{3} \times \frac{4}{3} \times \frac{4}{5} \times \frac{6}{5} \times \frac{6}{7} \times \frac{8}{7} \ldots$
    • [link to Wallis approximation](http://cs103.usc.edu/websheets/index.php#wallisapprox)
The Loops That Keep On Giving

- There's a problem with the loop below
- We all write "infinite" loops at one time or another
- Infinite loops never quit
- When you do write such a program, just type "Ctrl-C" at the terminal to halt the program

```cpp
#include <iostream>
using namespace std;
int main()
{
    int val;
    bool again = true;
    while(again = true){
        cout << "Enter an int or -1 to quit";
        cin >> val;
        if( val == -1 ) {
            again = false;
        }
    }
    return 0;
}
```

```cpp
#include <iostream>
using namespace std;
int main()
{
    int i=0;
    while( i < 10 ) {
        cout << i << endl;
        i + 1;
    }
    return 0;
}
```

http://blog.codinghorror.com/rubber-duck-problem-solving/
The Loops That Keep On Giving

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    int val;
    bool again = true;
    while(again == true){
        cout << "Enter an int or -1 to quit";
        cin >> val;
        if( val == -1 ) {
            again = false;
        }
    }
    return 0;
}
```

```cpp
#include <iostream>
using namespace std;
int main()
{
    int i=0;
    while( i < 10 ) {
        cout << i << endl;
        i = i + 1;
    }
    return 0;
}
```

Getting All The Inputs

• Notice another way to receive all the numbers entered by a user while (cin >> val)
  { // do stuff }

• In this approach cin does two things
  – It does receive input into the variable 'val'
  – It returns 'true' if it successfully got input, 'false' otherwise

• Keeps grabbing values one at a time until the user types Ctrl-D

```cpp
#include <iostream>
using namespace std;
int main()
{
    int val;
    // reads until user hits Ctrl-D
    // which is known as End-of-File(EOF)
    cout << "Enter an int or Ctrl-D ";
    cout << " to quit: " << endl;
    while (cin >> val){
        cout << "Enter an int or Ctrl-D "
        cout << " to quit" << endl;
        if(val % 2 == 1){
            cout << val << " is odd!" << endl;
        }
        else {
            cout << val << " is even!" << endl;
        }
    }
    return 0;
}"
```
Single Statement Bodies

- An if, while, or for construct with a single statement body does not require { ... }
- Another if, while, or for counts as a single statement

```
if (x == 5)
  y += 2;
else
  y -= 3;

for(i = 0; i < 5; i++)
  sum += i;

while(sum > 0)
  sum = sum/2;

for(i = 1; i <= 5; i++)
  if(i % 2 == 0)
    j++;
```
More Exercises

• Determine if a user-supplied positive integer > 1 is prime or not
  – How do we determine if a number is a factor of another?
  – What numbers could be factors?
  – How soon can we determine a number is not-prime?

• Reverse the digits of an integer\(^1\)
  – User enters 123 => Output 321
  – User enters -5293 => -3925
  – [http://cs103.usc.edu/websheets/index.php#revdigits](http://cs103.usc.edu/websheets/index.php#revdigits)

\(^1\)Taken from D.S. Malik, C++ Programming, 6\(^{th}\) Ed.
20-second Timeout: Chunking

• Right now you may feel overwhelmed with all the little details (all the parts of a for loop, where do you need semicolons, etc.)

• As you practice these concepts they will start to "chunk" together where you can just hear "for loop" and will immediately know the syntax and meaning

• Chunking occurs where something more abstract takes the place of many smaller pieces

“Chunking” allows complex tasks to become simple

Tooth Brushing
- Turn on faucet
- Rinse toothbrush
- Turn off faucet
- Remove cap from tooth paste
- Apply toothpaste to brush
- Replace cap
- Insert brush into mouth
- Brush teeth for 2 minutes
- Turn on faucet
- Spit
- Rinse mouth
- Rinse brush

https://designbyben.wordpress.com/tag/chunking/
NESTED LOOPS
Nested Loops

- Inner loops execute fully (go through every iteration before the next iteration of the outer loop starts)

```cpp
#include <iostream>
#include <iomanip>
using namespace std;

int main()
{
    for(int i=0; i < 2; i++){
        for(int j=0; j < 3; j++){
            // Do something based on i and j
            cout << i << " " << j;
            cout << endl;
        }
    }
    return 0;
}
```

Output:

```
0 0
0 1
0 2
1 0
1 1
1 2
```
Nested Loops

- Write a program using nested loops to print a multiplication table of 1..12
- Tip: Decide what abstract “thing” your iterating through and “read” the for loop as “for each “thing” ...
  - For each “row” ...
    - For each column...
      - print the product

```cpp
#include <iostream>

using namespace std;

int main()
{
  for(int r=1; r <= 12; r++)
  {
    for(int c=1; c <= 12; c++)
    {
      cout << r*c;
    }
  }
  return 0;
}
```

This code will print some not so nice output:

```
123456789101112246810121416
8202224...
```
**Nested Loops**

- Tip: Decide what abstract “thing” you’re iterating through and “read” the for loop as “for each “thing” ...
  - For each “row” ...
    - For each column...
      - Print the product followed by a space
    - Print a newline

```
#include <iostream>
using namespace std;

int main()
{
    for(int r=1; r <= 12; r++){
        for(int c=1; c <= 12; c++){
            cout <<  " " << r*c;
        }
        cout << endl;
    }
    return 0;
}
```

This code will still print some not so nice output:

```
1 2 3 4 5 6 7 8 9 10 11 12
2 4 6 8 10 12 14 16 18 20 22 24
```

```
1  2  3
1 1  2  3
2 2  4  6
3 3  6  9
```
Nested Loops

- Tip: Decide what abstract “thing” your iterating through and “read” the for loop as “for each “thing” ...
  - For each “row” ...
    - For each column... print the product

```cpp
#include <iostream>
#include <iomanip>
using namespace std;

int main()
{
  for(int r=1; r <= 12; r++)
  {
    for(int c=1; c <= 12; c++)
    {
      cout << setw(4) << r*c;
    }
    cout << endl;
  }
  return 0;
}
```

<table>
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<th></th>
<th>1</th>
<th>2</th>
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Nested Loop Practice

• 5PerLine series
  – http://cs103.usc.edu/websheets/index.php#5perlineA
  – http://cs103.usc.edu/websheets/index.php#5perlineB
  – http://cs103.usc.edu/websheets/index.php#5perlineC
  – Each exercise wants you to print out the integers from 100 to 200, five per line, as in:
    100 101 102 103 104
    105 106 107 108 109
    ...
    195 196 197 198 199
    200
**break and continue**

- **Break**
  - Ends the current loop [not if statement] immediately and continues execution after its last statement

- **Continue**
  - Begins the next iteration of the nearest loop (performing the update statements if it is a for loop)
  - Can usually be accomplished with some kind of if..else structure
  - Can be useful when many nested if statements...

```cpp
bool done = 0;
while ( !done )
{
    cout << "Enter guess: " << endl;
    cin >> guess;
    if( guess < 0 )
    {
        break;
    }
}
// ... Process guess

// Guess an int >= 0
while( !done ) {
    cin >> guess;
    if(guess < 0){
        continue;
    }
    // Can only be here if guess >= 0
}
// Equivalent w/o using continue
while( !done ) {
    cin >> guess;
    if(guess >= 0){
        // Process
    }
}
```
break and continue

• Break and continue apply only to the inner most loop (not all loops being nested)
  – Break ends the current (inner-most) loop immediately
  – Continue starts next iteration of inner-most loop immediately

• Consider problem of checking if a '!' exists anywhere in some lines of text
  – Use a while loop to iterate through each line
  – Use a for loop to iterate through each character on a particular line
  – Once we find first '!' we can stop

```cpp
bool flag = false;
while( more_lines == true ){  // get line of text from user
  length = get_line_length(...);
  for(j=0; j < length; j++){
    if(text[j] == '!'){
      flag = true;
      break; // only quits the for loop
    }
  }
}

bool flag = false;
while( more_lines == true && ! flag ){  // get line of text from user
  length = get_line_length(...);
  for(j=0; j < length; j++){
    if(text[j] == '!'){
      flag = true;
      break; // only quits the for loop
    }
  }
}
```
Common Loop Tasks

• **Aggregation / Reduction**
  – Sum or combine information from many pieces to a single value
  – E.g. Sum first 10 positive integers
  – Declare aggregation variable and initialize it outside the loop and update it in each iteration

```c
// aggregation example
int sum = 0;
for(int i=1; i <= 10; i++){
    sum += i;
}
```

• **Search for occurrence**
  – Find a particular occurrence of some value or determine it does not exist
  – Declare a variable to save the desired occurrence or status, then on each iteration check for what you are looking for, and set the variable if you find it and break the loop

```c
// search for first int divisible // by 2 and 3
int div2_3 = 0;
for(int i=1; i < 100; i++){
    if( i%2 == 0 && i%3 == 0){
        div2_3 = i;
        break;
    }
}
if( div2_3 != 0 ){
    // we have found such an int
}
C LIBRARIES & RAND()
Preprocessor & Directives

- Somewhat unique to C/C++
- Compiler will scan through C code looking for directives (e.g. `#include`, `#define`, anything else that starts with '#' )
- Performs textual changes, substitutions, insertions, etc.
- `#include <filename>` or `#include "filename"
  - Inserts the entire contents of "filename" into the given C text file
- `#define find_pattern replace_pattern`
  - Replaces any occurrence of `find_pattern` with `replace_pattern`
  - `#define PI 3.14159`
    - Now in your code:
      ```c
      x = PI;
      ```
      is replaced by the preprocessor with
      ```c
      x = 3.14159;
      ```
#include Directive

- Common usage: To include “header files” that allow us to access functions defined in a separate file or library
- For pure C compilers, we include a C header file with its filename: `#include <stdlib.h>`
- For C++ compilers, we include a C header file without the .h extension and prepend a ‘c’: `#include <cstdlib>`

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rand() and RAND_MAX

- (Pseudo)random number generation in C is accomplished with the `rand()` function declared/prototyped in `<cstdlib>`.
- `rand()` returns an integer between 0 and `RAND_MAX`.
  - `RAND_MAX` is an integer constant defined in `<cstdlib>`.
- How could you generate a flip of a coin [i.e. 0 or 1 w/ equal prob.]?
  ```
  int r;
  r = rand();
  if(r < RAND_MAX/2){ cout << "Heads"; }
  ```
- How could you generate a decimal with uniform probability of being between [0,1]
  ```
  double r;
  r = (double) rand() / (double) (RAND_MAX);
  ```
Seeding Random # Generator

• Re-running a program that calls rand() will generate the same sequence of random numbers (i.e. each run will be exactly the same)
• If we want each execution of the program to be different then we need to seed the RNG with a different value
• srand(int seed) is a function in <cstdlib> to seed the RNG with the value of seed
  – Unless seed changes from execution to execution, we’ll still have the same problem
• Solution: Seed it with the day and time [returned by the time() function defined in ctime]
  – srand(time(0)); // only do this once at the start of the program
  – int r = rand(); // now call rand() as many times as you want
  – int r2 = rand(); // another random number
  – // sequence of random #'s will be different for each execution of program

Only call srand() ONCE at the start of the program, not each time you want to call rand()!!!
PRACTICE
Another Exercise

- Guessing game
  - Number guessing game
    [0-19]...indicate higher or lower until they guess correctly or stop after 5 unsuccessful guesses

```cpp
#include <iostream>
#include <cstdlib>
#include <ctime>

int main()
{
    srand(time(0));
    int secretNum = rand() % 20;
    // Now create a game that
    // lets the user try to guess
    // the random number in up to
    // 5 guesses
}
```

Ch. 5, PE 16 of D.S. Malik, C++ Programming, 6th Ed.