CS 103 Lecture 3 Slides

Control Structures

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Announcements

- Lab 2 – Due Friday

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://bytes.usc.edu/cs103/in-class-exercises
    - printseconds
  - 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

If..else statements

MODULE 5: CONDITIONAL STATEMENTS

Comparison Operators

- Control structures like if, while, and for require conditions to determine what code should execute
- To perform comparison of variables, constants, or expressions in C/C++ we can use the basic 6 comparison operators

Operator(s)	Meaning	Example
`==`	Equality	`if(x == y)`
`!=`	Inequality	`if(x != 7)`
`<`	Less-than	`if(x < 0)`
`>`	Greater-than	`if(y > x)`
`<=`	Less-than OR equal to	`if(x <= -3)`
`>=`	Greater-than OR equal to	`if(y >= 2)`

Logical AND, OR, NOT

- Often want to combine several conditions to make a decision
- Logical AND => `x > 0 && y > 0`
- Logical OR => `x == 1 || x == 2`
- Logical NOT => `!(x < 0)`
- Precedence (order of ops.) => `!` then `&&` then `||`
  - `!cond1 || cond2 && !cond3`
  - `( ( !cond1 ) || (cond2 && ( !cond3 ) ) )`

A	B	AND
False	False	False
False	True	False
True	False	False
True	True	True

A	B	OR
False	False	False
False	True	True
True	False	True
True	True	True

A	NOT
False	True
True	False

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`

bools, ints, and Conditions

- Loops & conditional statements require a **condition** to be evaluated resulting in a `true` or `false` result.
- 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` = non-zero (usually 1) and
    - `false` = 0
- Any place a condition would be used a bool or int type can be used and will be interpreted as bool

```
int x = 100;
if(x)
  { x--; }
```

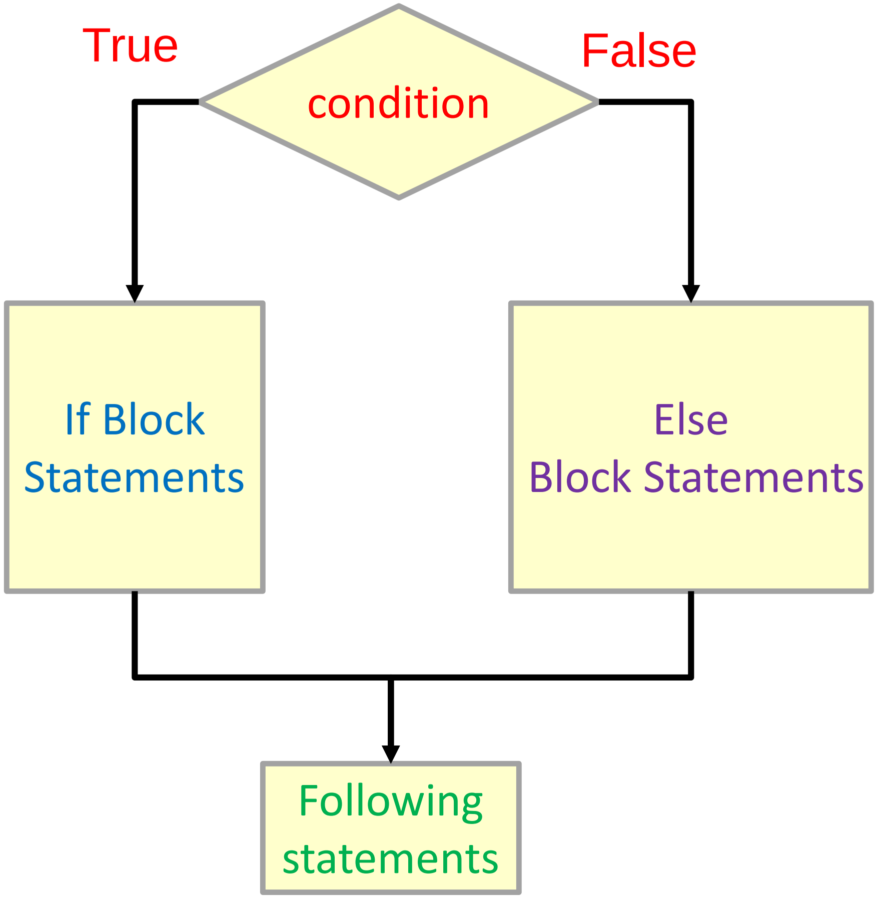
```
bool done = false;
while( ! done )
  { cin >> done; }
```

```
int x=100, y=3, z=0;
if( !x || (y && !z) )
  { /* code */ }
```

Conditions and DeMorgans

- Write a condition that eats a sandwich if it has neither tomato nor lettuce
  - `if ( !tomato && !lettuce)  { eat_sandwich(); }`
  - `if ( !(tomato || lettuce) ) { eat_sandwich(); }`
- DeMorgan's theorem says there is always two ways to express a logic condition
  - `!a && !b ⇔ !(a || b)`
  - `!a || !b ⇔ !(a && b)`
- More details in EE 109 and CS 170

If..Else Flow Chart

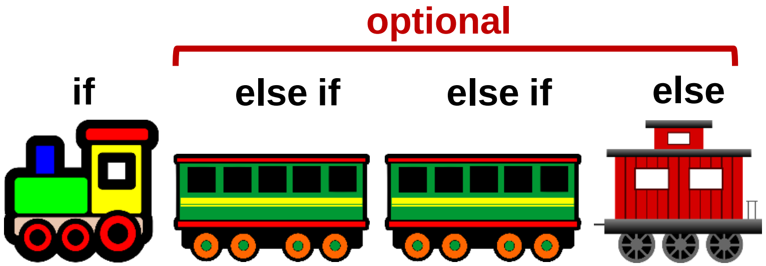


```
if (condition1)
{
  // executed if condition1 is true
}
else
{
  // executed if condition1
  // above is false
}

// following statements
```

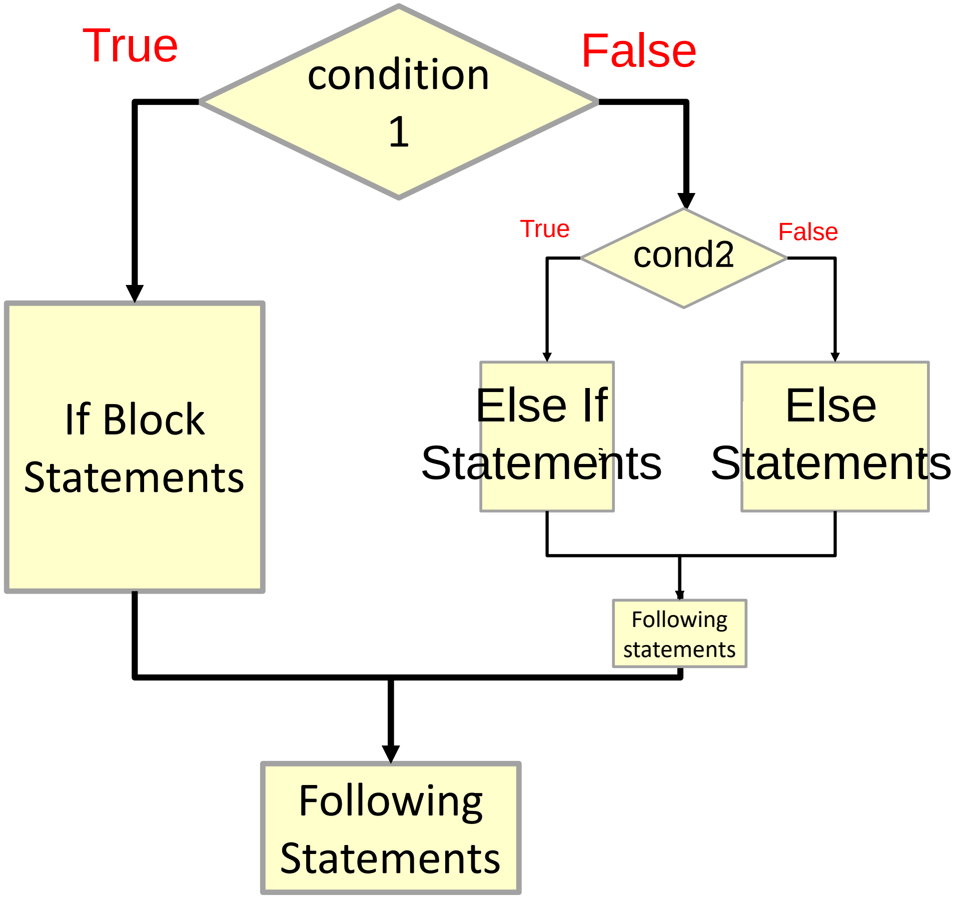
If…Else If…Else

- 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



```
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
}
```

else if



```
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
}
```

These 2 are equivalent

```
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
  }
}
```

Single Statement Bodies

- The Rule: Place code for an if, else if, or else construct in curly braces { … }
- The Exception:
  - An if or else construct with a single statement body does not require { … }
  - Another if counts as a single statement
- Prefer { … } even in single statement bodies so that editing later does not introduce bugs

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


if (x == 5)
  y += 2;
else
  if(x < 5)
    y = 6;
  else
    y = 0;
```

PROBLEM SOLVING IDIOMS

Rule/Exception Idiom

- **Name**: Rule/Exception
- **Description**: Perform a default action and then us an ‘if’ to correct for exceptional cases
- **Structure**: Default action code followed by if statement with code to correct the exceptional case
- **Example(s)**:
  - Shipping for "members"

```
// Default action

if( /* Exceptional Case */ )
{
   // Code to apply to
   // exceptional case
}
```

Structure

```
bool primeMember = /* set somehow */;

double shippingFee = 7.99;
if( primeMember == true )
{
   shippingFee = 0;
}
```

Example

Look-up Table Idiom

- **Name**: Look-up Table (Parallel cases)
  - A table can describe the mapping of input to output
- **Description**: Break input into **mutually exclusive** cases, taking some action or producing some output in each case
- **Structure**: Single level 'if..else if..else' statement

```
if( /* Condition 1 */ )
{
  // Case 1 code
}
else if( /* Condition 2 */ )
{
   // Case 2 code
}
else if( /* Condition 3 */ )
{
   // Case 3 code
}
else {  /* Default */
   // Default code
}
```

Look-up Table Structure

Score (input)	Grade (output)
> 90	A
80-89	B
70-79	C
55-69	D
< 55	F

Weather	Dress
Hot	T-shirt
Mild	Long Sleeves
Cold	Sweater

```
if( weather == "hot" ) {
  clothing = "t-shirt";
}
else if( weather == "mild" ) {
  clothing = "long sleeves";
}
else {  /* Default */
  clothing = "sweater";
}
```

Decision Tree (Subcase) Idiom

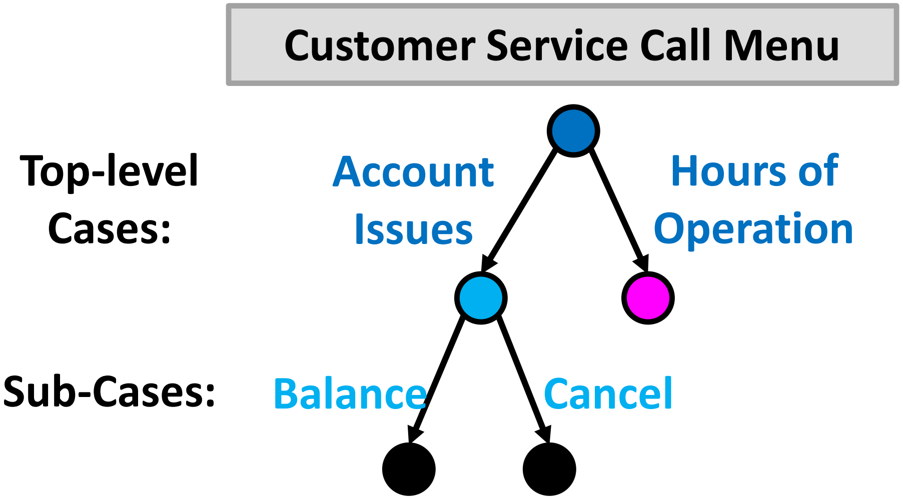
- **Name**: Decision Tree (Subcase)
- **Description**: The result of one condition determines which condition (subcase) to check next
- **Structure**: Nested 'if' statements

```
if( /* Condition 1 */ )
{
   // Case 1 code

   if( /* Subcondition 1a */ ) {
      // Subcase 1a code
   }
   else {
      // Subcase 1b code
   }

}
else if( /* Condition 2 */ )
{
   // Case 2 code

   if( /* Subcondition 2a */ ) {
      // Subcase 2a code
   }
}
```



Exercises

- Conditionals In-Class Exercises
  - discount
  - weekday
  - nth

The Right Style

- Is there a difference between the following two code snippets
- Both are equivalent but
  - Two if statements implies both can execute
  - An if..else implies a mutually exclusive relationship where only 1 can execute
- For mutually exclusive cases, use if..else for clarity sake

```
int x;
cin >> x;

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

```
int x;
cin >> x;

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

Find the bug

- What's the problem with this code…
- 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

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

```
// What’s the problem below
int x;
cin >> x;
if (x = 1) // 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
- *Cases must be a constant*
- Best used to select an action when an expression could be 1 of a set of constant 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

```
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

```
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;

}
```

? Operator

- A simple if..else statement can be expressed with the ? operator
  - `int x = (y > z) ? 2 : 1;`
  - Same as:

```
if(y > z)  x = 2;
else x = 1;
```

- Syntax: (*condition*) ? *expr_if_true* : *expr_if_false*;
- Meaning: the expression will result/return *expr_if_true* if *condition* evaluates to true or *expr_if_false* if *condition* evaluates to false

Performing repetitive operations

MODULE 6: LOOPS (ITERATIVE STATEMENTS)

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 try to achieve these without loops, but…

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

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

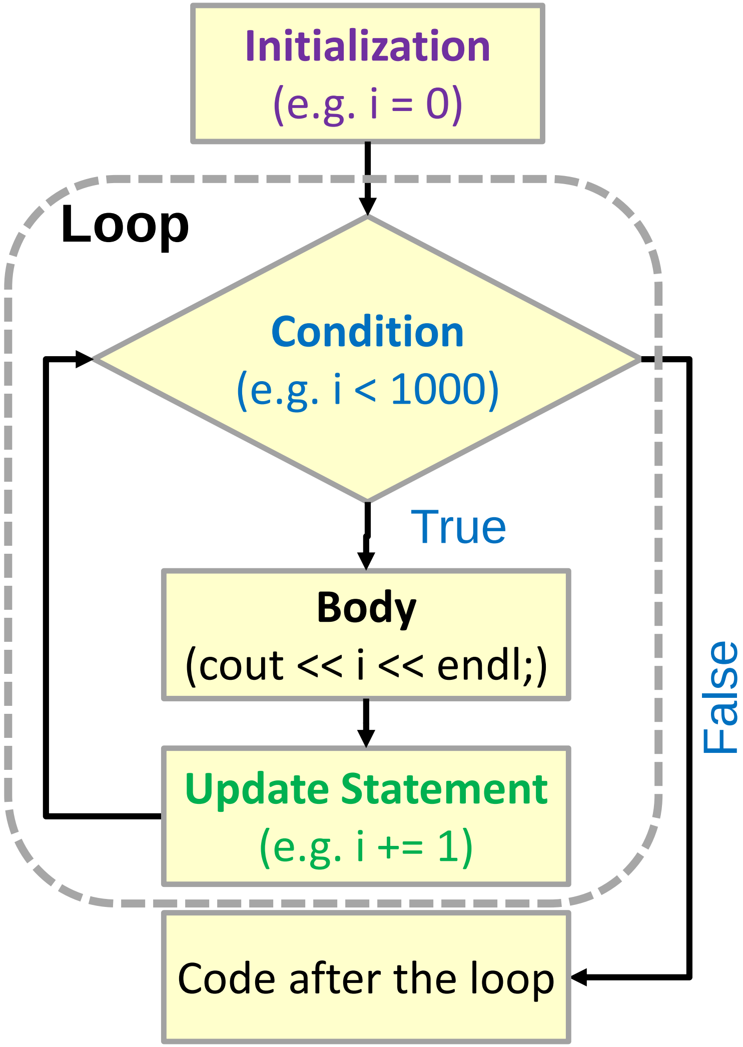
```
#include <iostream>
using namespace std;

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

Assume this performs code to "take a turn" and thenproduces a true/false result indicating if the game is over

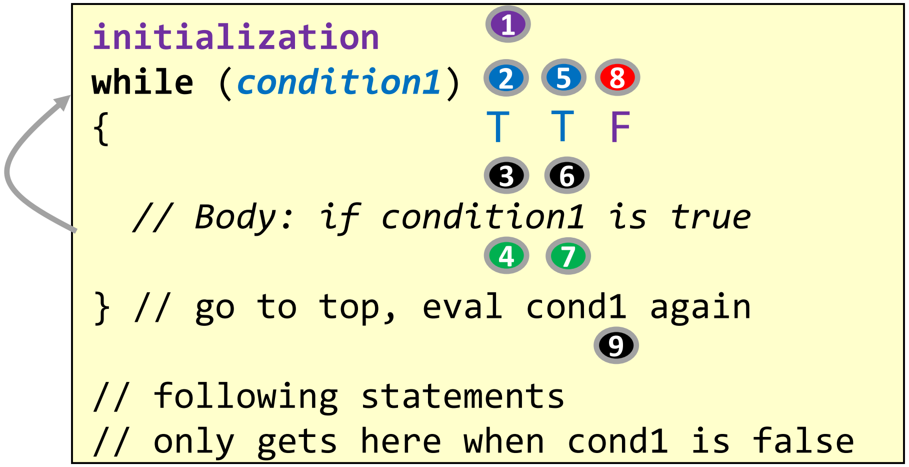
4 Necessary Parts of a Loop

- Loops involve writing a task to be repeated
- Regardless of that task, there must be **4 parts** to a make a loop work
- **Initialization**
  - Initialization of the variable(s) that will control how many iterations (repetitions) the loop will executed
- **Condition**
  - Condition to decide whether to repeat the task or stop the loop
- **Body**
  - Code to repeat for each iteration
- **Update**
  - Modify the variable(s) related to the condition



Type 1: while Loops

- A while loop is essentially a repeating 'if' statement



```
initialization
while (condition1)
{

  // Body: if condition1 is true

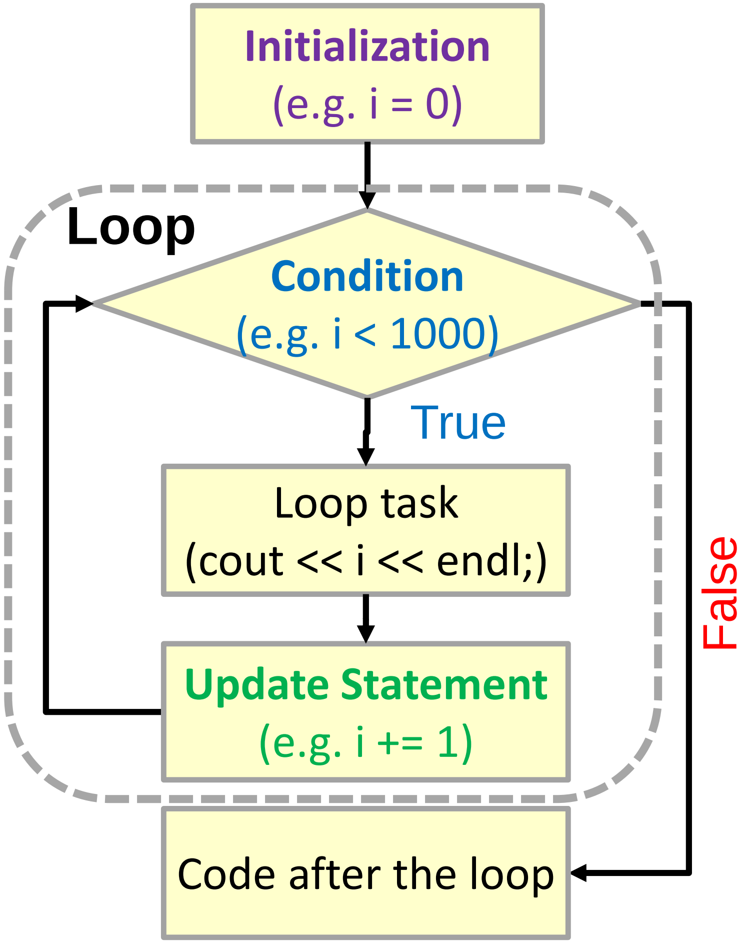
} // go to top, eval cond1 again

// following statements
// only gets here when cond1 is false
```

```
int i=0;
while (i < 1000)
{
  cout << i << endl;
  i++;
}

// following statements
```

While loop printing 0 to 999



while vs. do..while Loops

- while loops have two variations: while and do..while
- `while`
  - Cond is evaluated first
  - Body only executed if condition is true (**maybe 0 times**)
- `do..while`
  - Body is executed **at least once**
  - Cond is evaluated
  - Body is repeated if cond is true

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



// Do while:
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**'
  - "**Until they guess correctly**" is the same as "**while they do NOT guess correctly**"

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

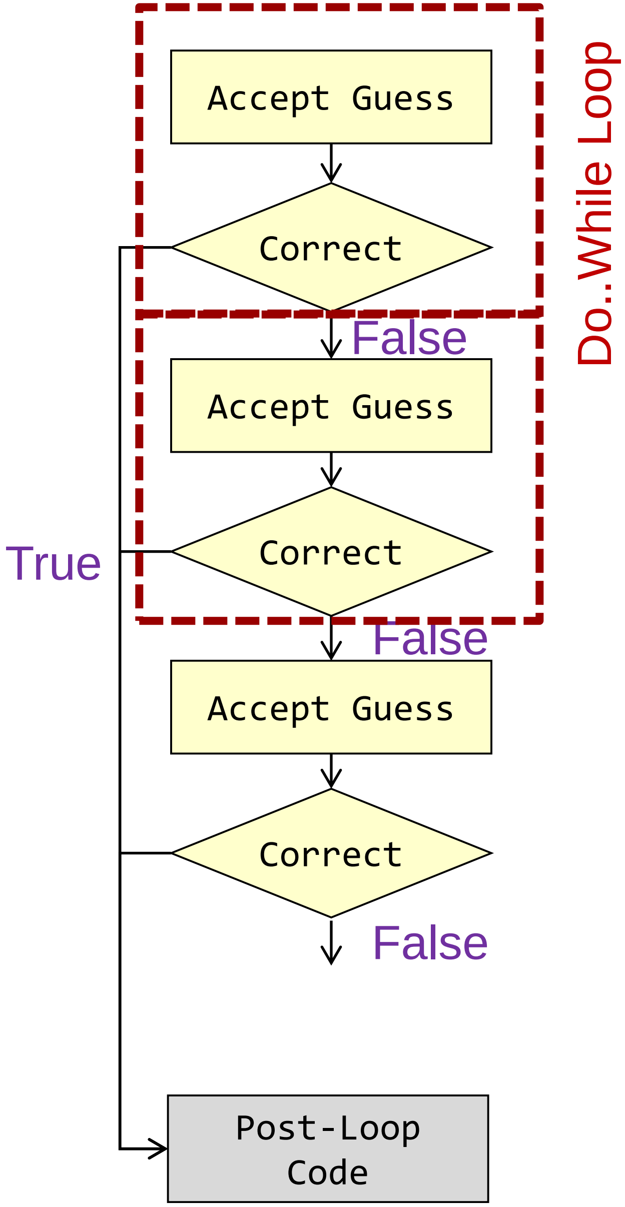
An if-statement will only execute once

```
// guessing game
bool guessedCorrect = false;

while( !guessedCorrect )
{
   guessedCorrect = guessAgain();
}
```

A 'while' loop acts as a repeating 'if' statement

Using Flow Charts to Find Loops

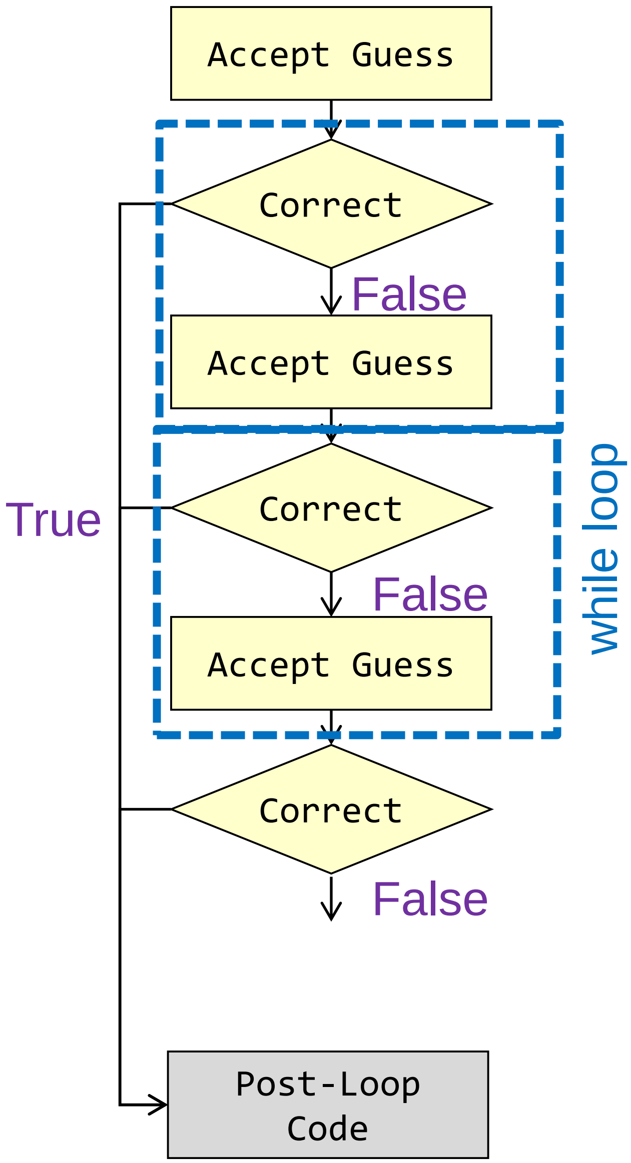


Draw out a flow chart of the desired sequence and look for the repetitive sequence

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

```
do
  { accept_guess }
while ( ! correct )
```

Finding the ‘while’ Structure



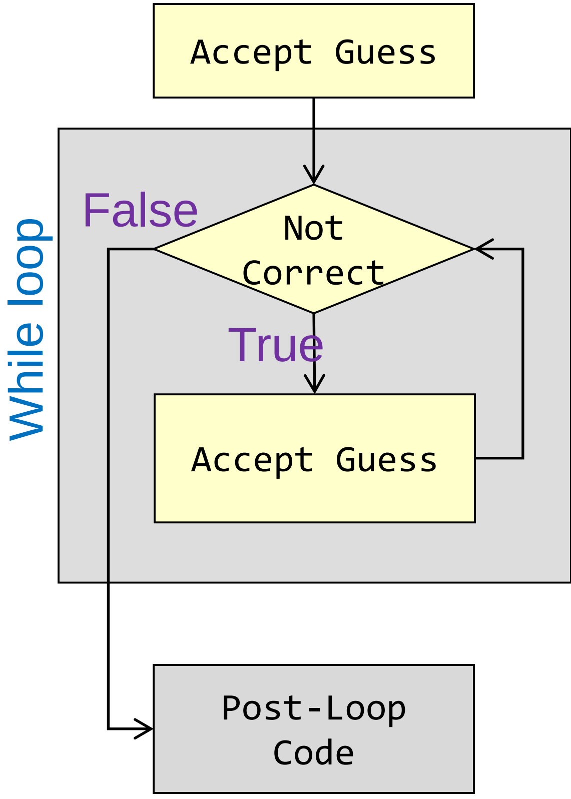
Draw out a flow chart of the desired sequence and look for the repetitive sequence

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

```
do
  { accept_guess }
while ( ! correct )
```

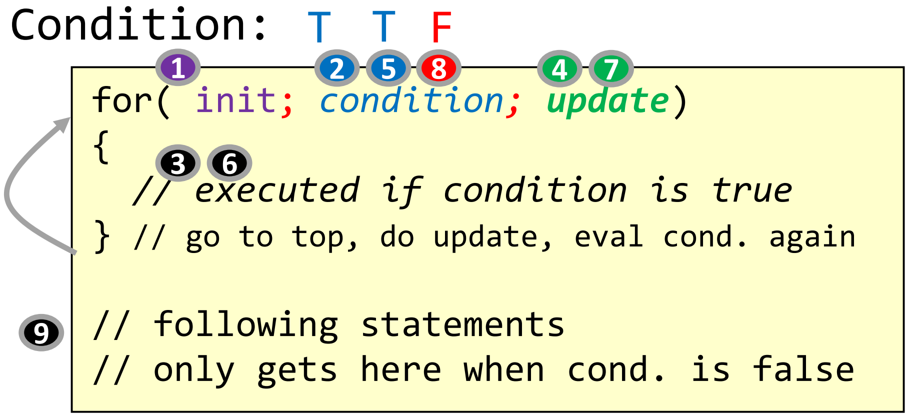
But a while loop checks at the beginning of the loop, so we must accept one guess before starting:

```
accept_guess
while( ! correct )
  { accept_guess }
```



Type 2: 'for' Loop

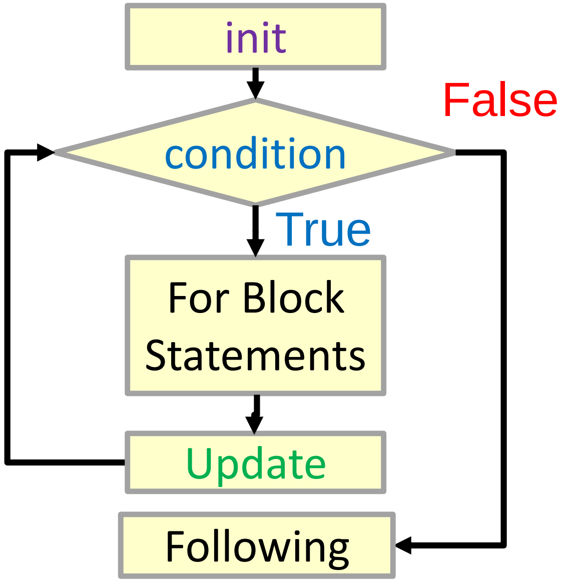
- 'for' loop
  - performs initialization statement once
  - checks the condition each iteration before deciding to execute the body or end the loop
  - performs the update statement after each execution of the body



Condition: T T F

```
for( init; condition; update)
{
  // executed if condition is true
} // go to top, do update, eval cond. again

// following statements
// only gets here when cond. is false
```



for Loop

- Initialization 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
  - Separate with commas

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

// Outputs 0 1 2 3 4 (on separate lines)
for(i=0; i < 5; i++){
  cout << i << endl;
}

// Outputs 0 5 10 15 … 95 (on sep. lines)
for(i=0; i < 20; i++){
  cout << 5*i << " is a multiple of 5";
  cout << endl;
}
// Same output as previous for loop
for(i=0; i < 100; i++){
  if(i % 5 == 0){
    cout << i << " is a multiple of 5";
    cout << endl;
  }
}

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

for vs. while Loop

- **'while' Rule of thumb**: Use when exact number of iterations is unknown when loop is started (i.e. condition updating inside the loop body)
- **'for' Rule of thumb**: Use when number of iterations is known when loop is started (independent of loop body)
- Both can be converted to the other…try it on the right

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

Notice we cannot predict how many times this will run.

```
int x;
cin >> x;
for(i=0; i < x; i++){
  cout << 5*i << " ";
}
cout << endl;
```

Though we don't know x we can say the loop will run exactly x times.

```
for(init stmt; cond; update stmt)
{
  // body of loop
}
// Equivalent while structure
```

LOOP IDIOMS & PRACTICE

Map Idiom

- **Name**: Map
- **Description**: Convert (map) each value in a collection to another value
- **Structure**: Use a loop to process a series of input values and convert to the desired output values
  - Usually with a n-to-n input-output relationship
- **Example(s)**:
  - See examples on the right

```
for(/* loop thru each input */)
{
   // Get next input, x
   // Produce next output, f(x)
}
```

Structure

Output the first *n* odd integers

```
Input:  0, 1, 2, ..., n-1
Output: 1, 3, 5,     , 2(n-1)+1
```

Given a threshold of 70, indicate if students have passed a quiz

```
Input:  78, 61, 85, 93, 54
Output: T,  F,  T,  T,  F
```

Take the absolute value of each input

```
Input:  -18, -13, 36, 2, -21
Output:  18,  13, 36, 2,  21
```

Reduce Idiom

- **Name**: Reduce / Combine / Aggregate
- **Description**: Combine/reduce all elements of a collection to a single value
- **Structure**: Use a "reduction" variable and a loop to process a series of input values, combining each of them to form a single (or constant number of) output value in the reduction variable
  - An n-to-1 input-output relationship
- **Example(s)**:
  - See example on the right

```
// Declare reduction variable, r
// Set r to identity value

for(/* loop thru each input */)
{
   // Get next input, x
   // Update r using x
}
```

Structure

Average a series of 4 numbers

Input: 2, 3, 1, 8
Average: 3.5

```
double sum = 0;
double x;
for(int i=0; i < 4; i++)
{  cin >> x;
   sum += x;
}
cout << sum / 4.0 << endl;
```

Selection Idiom

- **Name**: Selection
- **Description**: Select a subset (possibly one or none) of elements from a collection based on a particular property
- **Structure**: Loop through each element and check whether it meets the desired property. If so, perform a *map*, *reduce*, or other *other update* operation.
- **Example(s)**:
  - Count all *positive* integers inputs

```
// declare/initialize any state variables
// needed to track the desired result

// loop through each instance
for( /* each input, i */ ) {
   // Check if input meets the property
   if(property is true for i) {
      // Update state (variables) as needed
    }
}
// Output the state variables
```

Structure

Count Positive Integers

```
Input:   2, -3, -1, 8
Output: 2
```

Exercises

- In-class exercises:
  - countodd
  - liebnizapprox
  - wallis
  - revdigits

Loop Practice

- Write a for loop to compute the first 10 terms of the Liebniz approximation of π/4:
  - π/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
- In-class exercise:
  – liebnizapprox

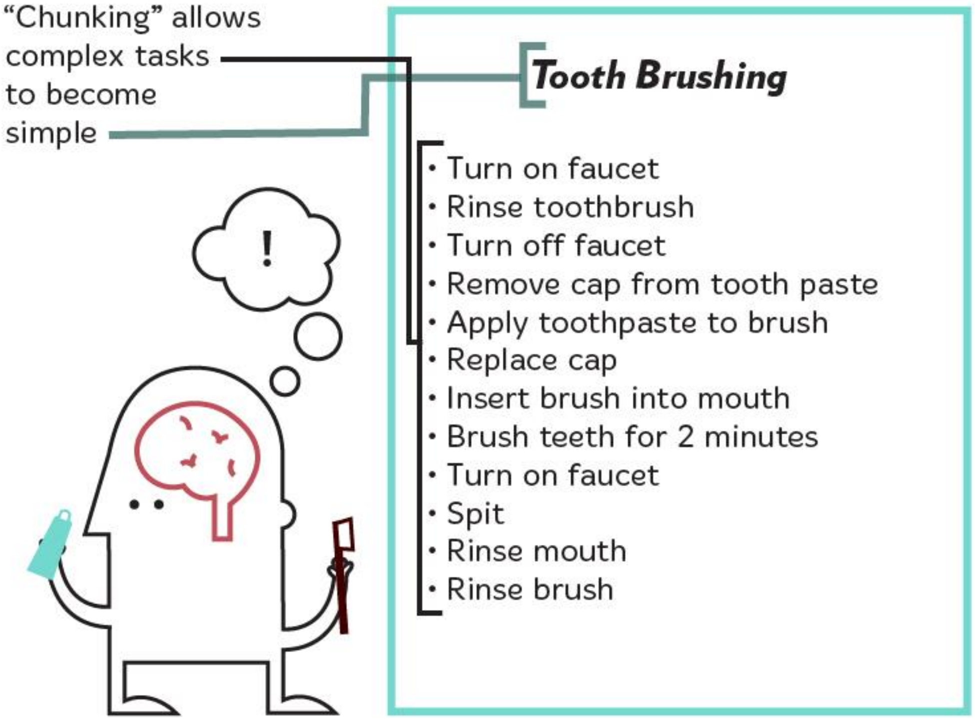
Counter (i)	Desired	Pattern	Counter (i)	Desired	Pattern
0	+1/1	for(i=0;i<10;i++)	1	+1/1	for(i=1; i<=19; i+=2)
1	-1/3	Fraction:	3	-1/3	Fraction:
2	+1/5		5	+1/5	
…	…	+/- =>	…	…	+/- =>
9	-1/19		19	-1/19	

Loop Practice

- Write for loops to compute the first 10 terms of the following approximations:
  - e^x: $1 + x + x^2/2! + x^3/3! + x^4/4!$ …
    - Assume 1 is the 1st term and assume functions
      - fact(int n) // returns n!
      - pow(double x, double n) // returns x^n
  - Wallis:
    - $\pi/2 = 2/1 * 2/3 * 4/3 * 4/5 * 6/5 * 6/7 * 8/7$ …
    - In-class Exercise
      - wallisapprox

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/

On your own time, practice tracing the following loops

TRACING EXECUTION 1

Tracing Exercises (Individually)

- To understand a loop's execution make a table of relevant variable values and show their values at the time the condition is checked
- If the condition is true perform the body code on your own (i.e. perform specified actions), do the update statement, & repeat

i (at condition check)	Actions of body
0	"0 "
1	"1 "
2	"2 "
3	"3 "
4	"4 "
5	-
Done	"0 1 2 3 4 15\n"

```
int i;
cout << "For 1: " << endl;
for(i=0; i < 5; i++){
  cout << i << " ";
}
cout << i+10 << endl;
```

Tracing Exercises (for 2-4)

- Perform hand tracing on the following loops to find what will be printed:

```
int i;

cout << "For 2: " << endl;
for(i=0; i < 5; i++){
  cout << 2*i+1 << " ";
}
cout << endl;
```

```
int i, j=1;

cout << "For 3: " << endl;
for(i=0; i < 20; i+=j){
  cout << i << " ";
  j++;
}
cout << endl;
```

```
int i, j=1;

cout << "For 4: " << endl;
for(i=10; i > 0; i--){
  cout << i+j << " ";
  i = i/2; j = j*2;
}
cout << endl;
```

Answers at end of slide packet

Tracing Exercises (for 5-6)

- Perform hand tracing on the following loops to find what will be printed:

```
int i = 3;
char c = 'a';

cout << "For 5: " << endl;
for( ; c <= 'j';  c+=i ){
  cout << c << " ";
}
cout << endl;
```

```
double T = 8;

cout << "For 6: " << endl;
for(i=0; i <= T; i++){
  // Force rounding to 3 decimal places
  cout << fixed << setprecision(3);
  // Now print the number
  cout << sin(2*M_PI*i/T) << endl;
}
```

Answers at end of slide packet

Tracing Exercises (while 1-2)

- Perform hand tracing on the following loops to find what will be printed:

```
int i=15, j=4;
cout << "While loop 1: " << endl;
while( i > 5 && j >= 1){
  cout << i << " " << j << endl;
  i = i-j;
  j--;
}
```

```
int i=1; j=1;
cout << "While loop 2: " << endl;
while( i || j ){
  if(i && j){
    j = !j;
  }
  else if( !j ){
    i = !i;
  }
  cout << i << " " << j << endl;
}
```

Answers at end of slide packet

Tracing Exercises (while 3)

- Perform hand tracing on the following loops to find what will be printed:

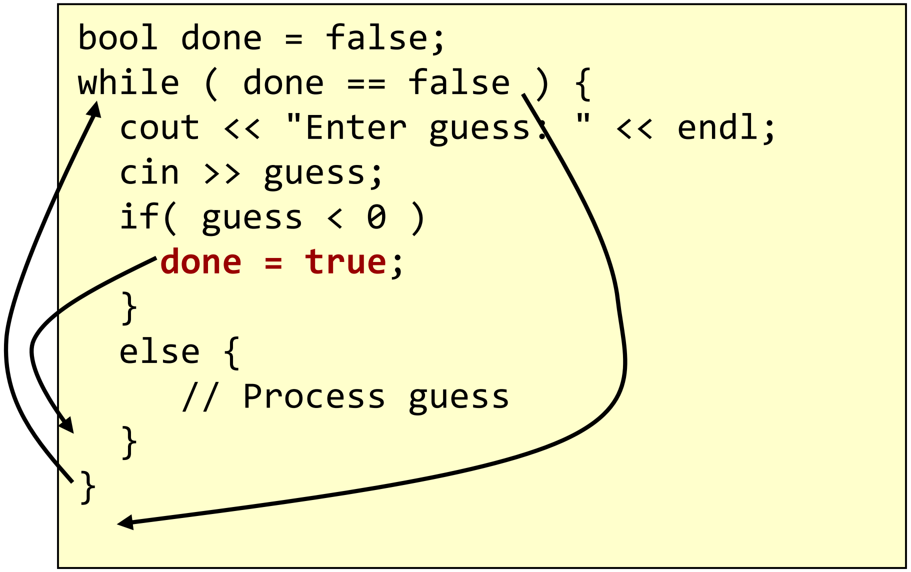
```
cout << "While loop 3: " << endl;
bool found = false;
int x = 7;
while( !found ){
  if( (x%4 == 3) &&
      (x%3 == 2) &&
      (x%2 == 1) )
  {
    found = true;
  }
  else {
    x++;
  }
}
cout << "Found x = " << x << endl;
```

Answers at end of slide packet

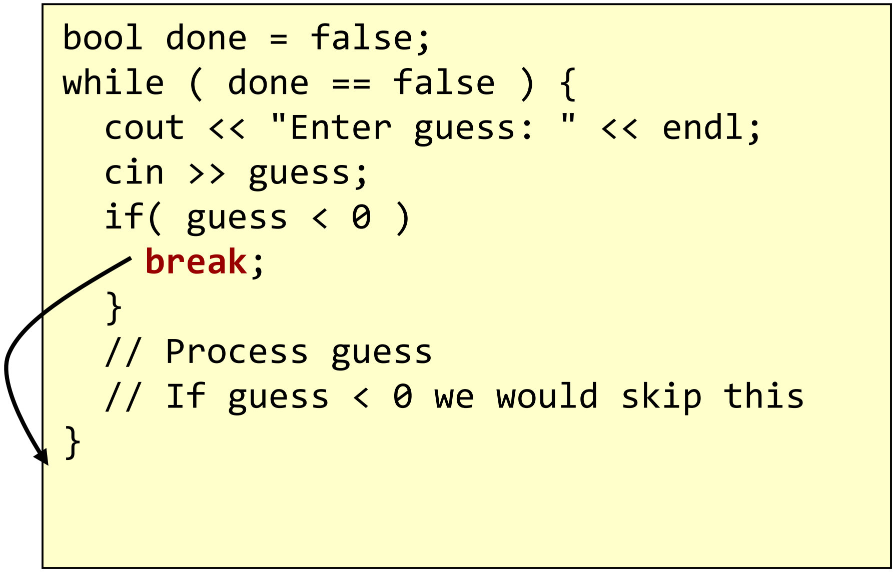
LOOP ODDS & ENDS

break statement

- break
  - Ends the current **loop** [not **if** statement] immediately and continues execution after its last statement
- Consider two alternatives for stopping a loop if an invalid (negative) guess is entered



```
bool done = false;
while ( done == false ) {
  cout << "Enter guess: " << endl;
  cin >> guess;
  if( guess < 0 )
    done = true;
  }
  else {
     // Process guess
  }
}
```



```
bool done = false;
while ( done == false ) {
  cout << "Enter guess: " << endl;
  cin >> guess;
  if( guess < 0 )
    break;
  }
  // Process guess
  // If guess < 0 we would skip this
}
```

continue statement

- continue
  - Ends the current **loop** [not **if** statement] immediately and continues execution after its last statement
- Consider two alternatives for repeating a loop to get a new guess if an invalid (negative) guess is entered
  - **Often continue can be eliminated by changing the if condition**

```
bool done = false;
while ( done == false ) {
  cout << "Enter guess: " << endl;
  cin >> guess;
  if( guess >= 0 ) {
    // Process Guess
  }
}
```

```
bool done = false;
while( done == false) {
  cout << "Enter guess: " << endl;
  cin >> guess;
  if(guess < 0){
    continue;
  }
  // Process guess (only here if guess>=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++;
```

The Loops That Keep On Giving

- There's a problem with the loops 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

```
#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;
}
```

```
#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/

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    }
  }
  return 0;
}
```

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

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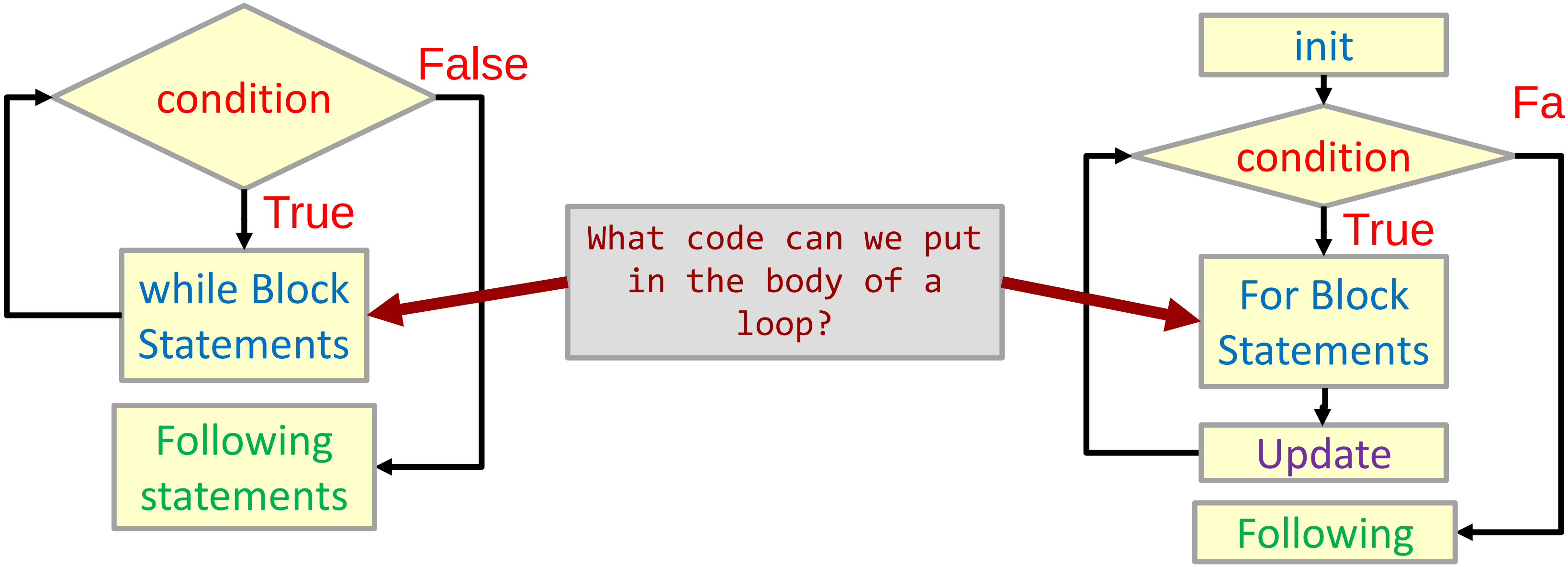
NESTED LOOPS

What Can Go Inside?

- What kind of code can we put in the body of a loop?
- ANYTHING…even other loops

```
while (condition)
{
  // What can go here?
}
```

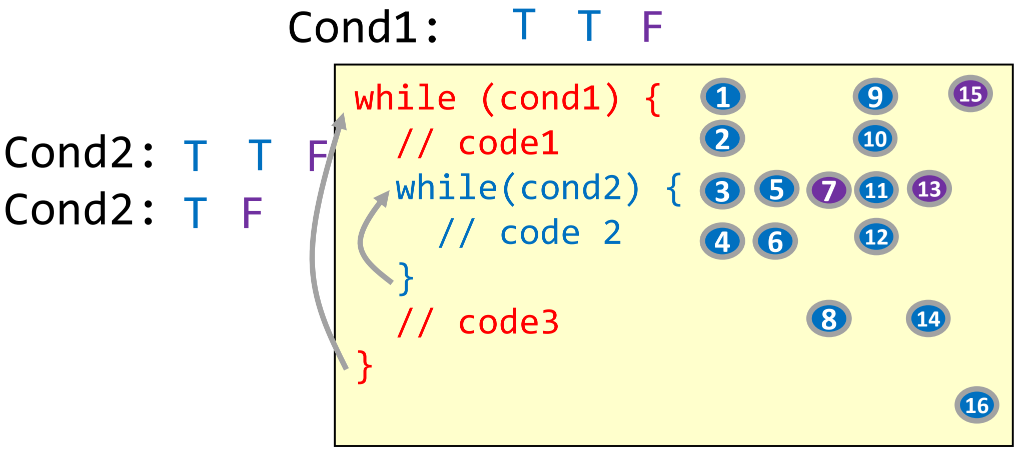
```
for( init; condition; update)
{
  // What can go here?
}
```



What code can we put in the body of a loop?

Nested Loop Sequencing

- **Key Idea**: The inner loop runs in its entirety for each iteration of the outer loop

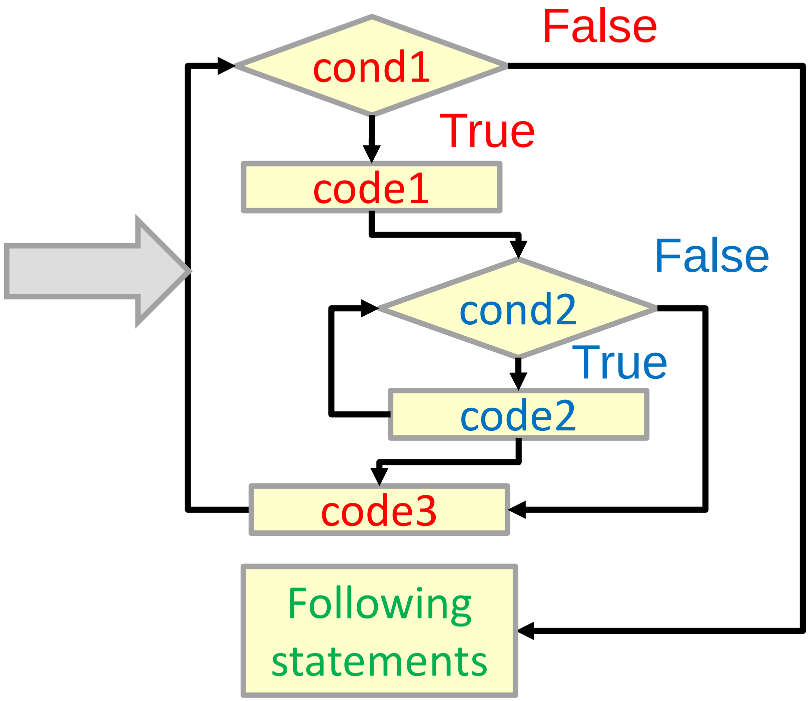


Cond1: T T F

Cond2: T T F

Cond2: T F

```
while (cond1) {
  // code1
  while(cond2) {
    // code 2
  }
  // code3
}
```



Nested Loops Example 1

- When you write loops consider what the body of each loop means in an abstract sense
  - The body of the outer loop represents 1 game (and we repeat that over and over)
  - The body of the inner loop represents 1 turn (and we repeat turn after turn)

```
int main()
{
  int secret, guess;
  char again = 'y';
  // outer loop
  while(again == 'y')
  {  // Choose secret num. 0-19
     secret = rand() % 20;
     guess = -1;
     // inner loop
     while(guess != secret)
     {
       cout << "Enter guess: ";
       cin >> guess;
     }
     cout << "Win!" << endl;
     cout << "Play again (y/n): ";
     cin >> again;
  }
  return 0;
}
```

1 game

1 turn

Nested Loops

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

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

int main()
{
  for(int i=0; i < 2; i++){
    for(int j=0; j < 3; j++){

      cout << i << " " << j << endl;
    }
  }
  return 0;
}
```

Output:

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

	1	2	3
1	1	2	3
2	2	4	6
3	3	6	9

```
#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:

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 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

- Use the `setw` I/O manipulator to beautify the output

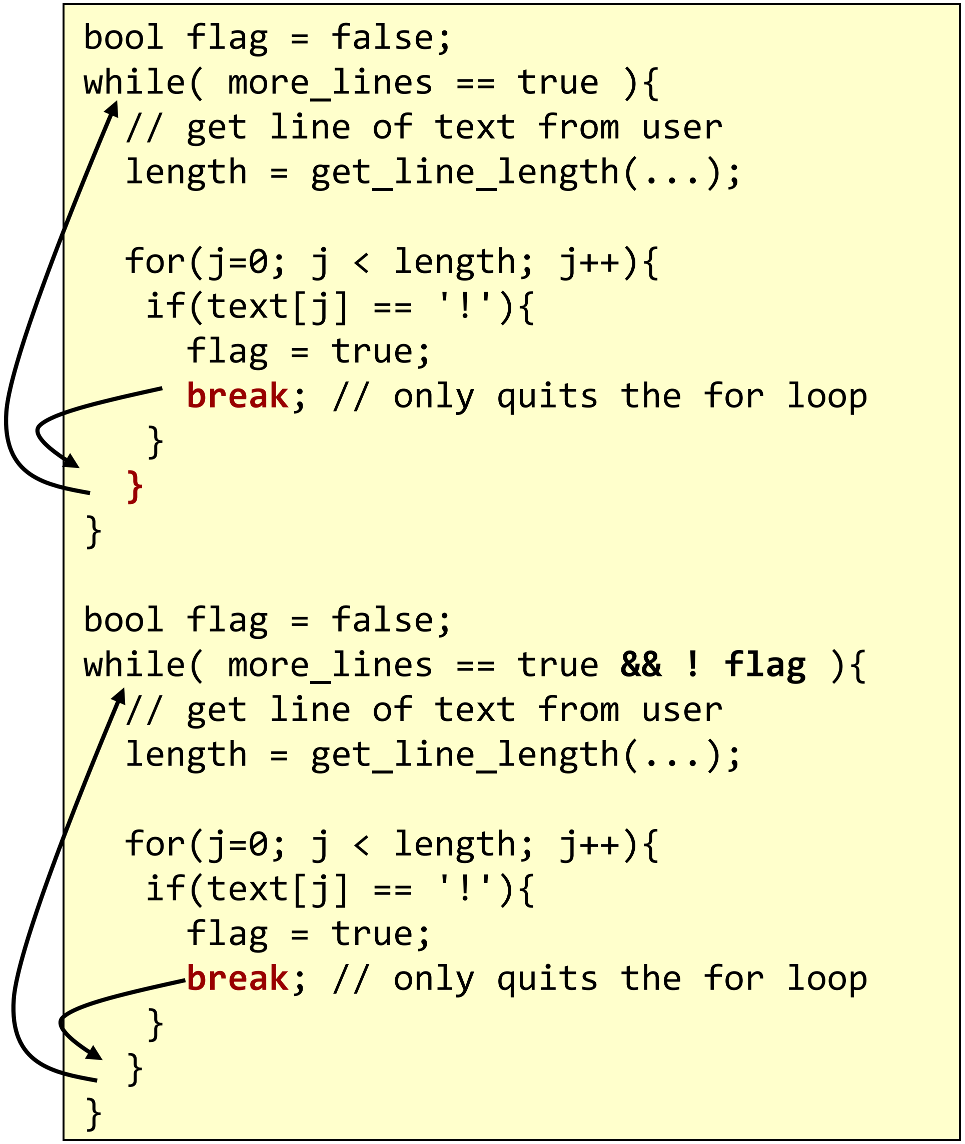
```
#include <iostream>
#include <iomanip>
using namespace std;

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;
}
```

	1	2	3
1	1	2	3
2	2	4	6
3	3	6	9

break and continue (Nested Loops)

- 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



```
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
   }
  }
}
```

Nested Loop Practice

- In class exercises: checkerboard and flag
- In class exercise: 5PerLineA
  - Try 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
```

- In class exercise: 5PerLineB and 5PerLineC each have an error. W ee what they print and determine the error.

MODULE 7: 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:

    ```
    x = PI;
    ```

    is replaced by the preprocessor with

    ```
    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>

C	Description	C++	Description
stdio.h **cstdio**	C Input/Output/File access (printf, fopen, snprintf, etc.)	**iostream**	I/O and File streams (cin, cout, cerr)
stdlib.h **cstdlib**	rand(), Memory allocation, etc.	**fstream**	File I/O (ifstream, ofstream)
string.h **cstring**	C-string library functions that operate on character arrays	**string**	C++ string class that defines the ‘string’ object
math.h **cmath**	Math functions: sin(), pow(), etc.	**vector**	Array-like container class

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 = staic_cast<double>(rand()) / 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() <u>ONCE</u> at the start of the program, not each time you want to call rand()!!!

Approximate rand() function:

```
val = ((val * 1103515245) + 12345) % RAND_MAX;
```

SOLUTIONS

Loop Practice

- Write a for loop to compute the first 10 terms of the Liebniz approximation of π/4:
  - π/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

Counter (i)	Desired	Pattern	Counter (i)	Desired	Pattern
0	+1/1	for(i=0; i <10; i++) Fraction: 1/(2*i+1) +/- => pow(-1,i) if(i is odd) neg.	1	+1/1	for(i=1; i <=19; i+=2) Fraction: 1/i +/- => if(i%4==3) neg.
1	-1/3		3	-1/3	
2	+1/5		5	+1/5	
…	…		…	…	
9	-1/19		19	-1/19	

Tracing Answers

```
For 1:
0 1 2 3 4 15

For 2:
1 3 5 7 9

For 3:
0 2 5 9 14

For 4:
11 6 5

For 5:
a d g j

For 6:
0.000
0.707
1.000
0.707
0.000
-0.707
-1.000
-0.707
-0.000
```

```
While loop 1:
15 4
11 3
8 2
6 1

While loop 2:
1 0
0 0

While loop 3:
Found x = 11
```