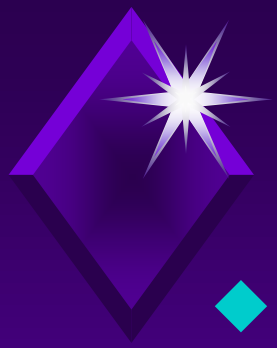
Chapter 6: Repetition Statements

Mr. Dave Clausen
La Cañada High School



Objectives

- Design and test repetition statements
- Understand the difference between a pretest loop and a posttest loop
- Understand the difference between a fixed repetition loop and a variable condition loop
- Choose a **for** loop, a **while** loop, or a **do-while** loop for a given problem

Repetition Statements

- Our third control structure: iteration or repetition (completes our 3 control structures: sequence, selection, iteration)
- Two main categories of repetition:
  - definite loop
    - repeats a predetermined number of times
  - indefinite loop
    - repeats a number of times that has not been predetermined.

Repetition Forms

- Three loop types:
  - for<a definite number of times> <do action>
  - while<condition is true> <do action>
  - do<action> while <condition is true>
- Three basic constructs
  - A variable is assigned some value.
  - The value of the variable changes at some point in the loop.
  - The loop repeats until the variable reaches a predetermined value, the program then executes the next statement after the loop.

Pretest Loops

- Pretest Loop (Entrance Controlled Loops)
  - a loop where the control condition (Boolean expression) is tested BEFORE the loop.
  - If the condition is true, the loop is executed.
  - If the condition is false the loop is not executed
  - Therefore, it is possible that these loops may not be executed at all (when the condition is False)
  - There are two pretest loops
    - for loop
    - while loop

Post Test Loops

- Post Test Loops (exit-controlled loop)
  - a loop where the control condition (Boolean expression) is tested AFTER the loop has been executed.
  - If the condition is true, the loop is executed again.
  - If the condition is false the loop is not executed again
  - Therefore, this type of loop will always be executed at least once.
  - There is one post test loop: do…while

Fixed repetition loops

- Fixed repetition loop
  - a loop used when you know in advance how many repetitions need to be executed.
  - also known as a definite loop:
    - (you know the definite number of repetitions necessary to solve the problem)
  - the “for” loop is:
    - a fixed repetition loop
    - and a pretest loop

Variable Condition Loops

- Variable Condition Loops
  - needed to solve problems where the conditions change within the body of the loop.
  - Also called indefinite loops:
    - the loop repeats an indefinite number of iterations until some condition is met, or while some condition is met.
    - The loop terminates depending upon conditions involving sentinel values, Boolean flags, arithmetic expressions, end of line, or end of file markers.
    - While and do…while loops are variable condition loops.

The for Loop

- General form:

for(<initialization expression>; <termination conditon>; <update expression>)

<statement>

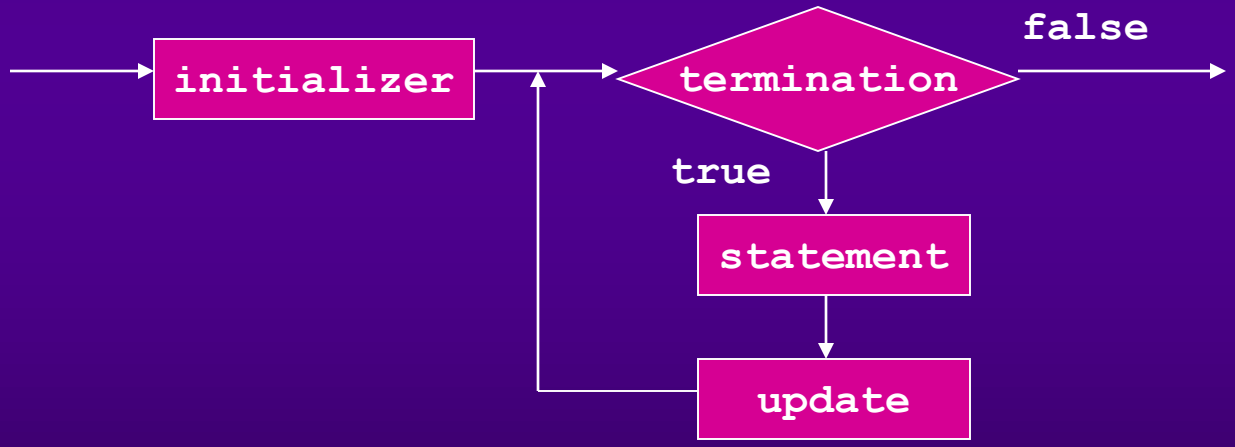
```
for (counter = 1; counter <= 10; counter = counter+1)     //Loop Heading
    cout<< counter << endl;                               //Loop body
```

Syntax and Semantics of the `for` Loop

```
for (<initializer>; <termination>; <update>)
    <statement>
```

Loop header

Loop body



The for Loop Internal Logic

- The control variable is assigned an initial value in the initialization expression
- The termination condition is evaluated
- If termination condition is true
  - the body of the loop is executed and the update expression is evaluated
- If the termination condition is false
  - program control is transferred to the first statement following the loop.

Increment Operator

- The Increment operator adds 1 to the variable
- Instead of x = x + 1 you can write as + +x
  - if the + + occurs before the x (+ + x) it is called a prefix operator
  - if the + + occurs after the x (x+ +) it is called a postfix operator
- Our text uses the prefix operator
  - **But let's use the postfix operator, x++**

Decrement Operator

- The Decrement operator subtracts 1 from the variable
- Instead of x = x - 1 you can write as --x
  - if the -- occurs before the x (-- x) it is called a prefix operator
  - if the -- occurs after the x (x--) it is called a postfix operator
- Our text uses the prefix operator
  - **But let's use the postfix operator, x- -**

Accumulator

- An **accumulator** is a variable used to keep a running total or sum of successive values of another variable
  - i.e. sum = sum + grade;
  - you should initialize the value of the accumulator before the loop: sum = 0;
  - the accumulator statement occurs in the body of the loop

```
//counter --> means loop control variable
sum=0;
for (counter = 1; counter <= 100; counter++)
   sum = sum + counter ;
```

Scope of Loop Control Variable

- The loop control variable must be declared before it is used.
  - The rules for the scope of the variable apply here
- If the variable is only going to be used as a loop counter, and for nothing else…
  - You can limit it's scope by declaring it when it is initialized in the loop

```
for(int counter = 1; counter <=10; counter ++)
   cout<< counter <<endl;
// counter is only referenced in loop
```

For Loops

- For loops can count down (decrement)

```
for (int counter=20; counter>=15; counter--)
    cout<< counter << endl;
```

- For loops can count by factors other than one

```
for(int counter=2; counter<=10; counter=counter+2)
    cout<< counter << endl;
```

  - Style
    - Indent the body of the loop, use blank lines before and after, and use comments.

While Loops

- General form:

  while (<Boolean expression>)

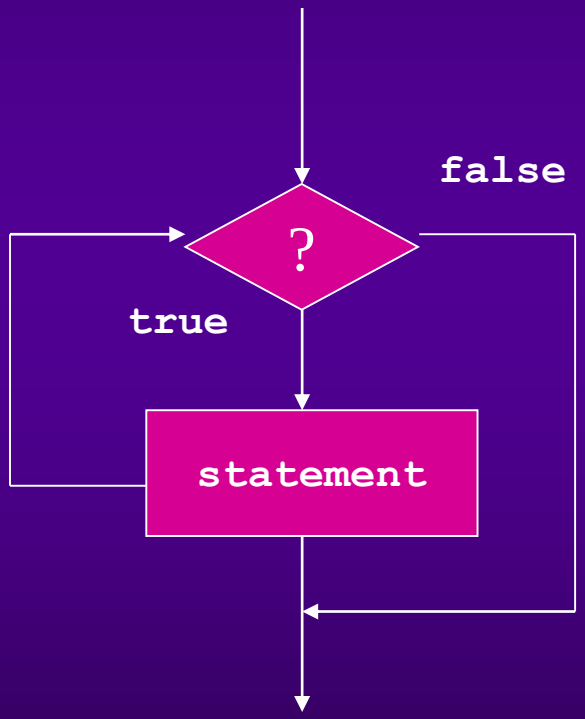
  <statement>

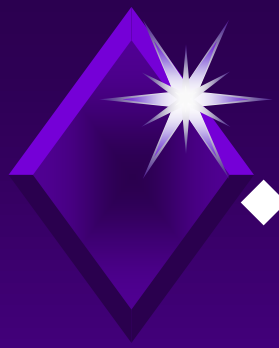
  - The parentheses around the Boolean is required.
  - If the condition is true the body of the loop is executed again.
  - If the loop condition is false, the program continues with the first statement after the loop.
  - A while loop may not be executed… why?

Syntax and Semantics of **`while`** *Statements*

```
while (<Boolean expression>)
    <statement>
```

```
while (<Boolean expression>)
{
    <statement 1>
    .
    <statement n>
}
```





While Loops: Discussion

- The condition can be any valid Boolean Expression
- The Boolean Expression must have a value PRIOR to **entering** the loop.
- The body of the loop can be a compound statement or a simple statement.
- The loop control condition needs to change in the loop body
  - If the condition is true and the condition is not changed or updated, an infinite loop could result.
  - If the condition is true and never becomes false, this results in an infinite loop also.

The while Loop Accumulator

Write code that computes the sum of the numbers between 1 and 10.

```
int counter = 1;
int sum = 0;
while (counter <= 10)
{
    sum = sum + counter;
    counter = counter + 1;
}
```

Sentinel Values and Counters

- Sentinel Value
  - A value that determines the end of a set of data, or the end of a process in an indefinite loop.

    P309EX1Dev.CPP
  - While loops may be repeated an indefinite number of times.
    - It is common to count the number of times the loop repeats.
    - Initialize this “counter” before the loop
    - Increment the counter inside the loop

do…while loops

- General form:

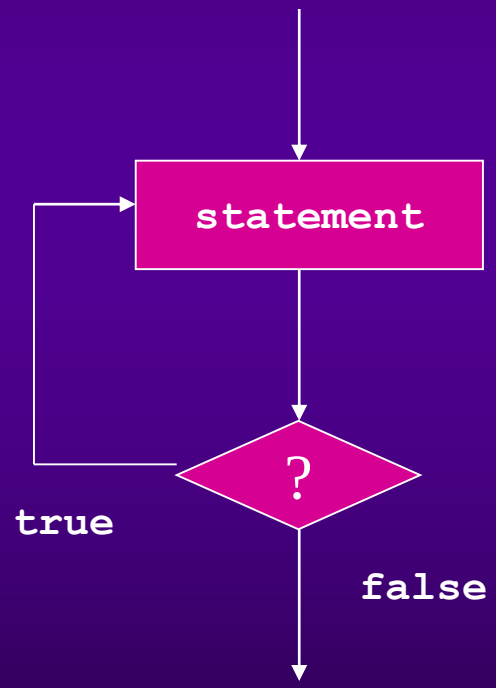
```
do
{
    <statement>
 }while (<Boolean expression>)
```

  - The Boolean expression must have a value before it is executed at the **end** of the loop.
  - If the loop condition is true, control is transferred back to the top of the loop.
  - If the loop condition is false, the program continues with the first statement after the loop.
  - A do...while loop will always be executed at least once… why?

*Syntax and Semantics of do…**while** Statements*

```
do
{
   <statement>
}while (<Boolean expression>);

do
{
   <statement 1>
   .
   <statement n>
} while (<Boolean expression>);
```



do…while Loops: Discussion

- The condition can be any valid Boolean Expression
- The Boolean Expression must have a value PRIOR to **exiting** the loop.
- The body of the loop is treated as a compound statement even if it is a simple statement. { }
- The loop control condition needs to eventually change to FALSE in the loop body
  - If the condition never becomes false, this results in an infinite loop.

Choosing which loop to use.

- for loop
  - when a loop is to be executed a predetermined number of times.
- while loop
  - a loop repeated an indefinite number of times
  - check the condition before the loop
  - a loop that might not be executed (reading data)
- do...while
  - a loop repeated an indefinite number of times
  - check the condition at the end of the loop

Designing Correct Loops

- Initialize all variables properly
  - Plan how many iterations, then set the counter and the limit accordingly
- Check the logic of the termination condition
- Update the loop control variable properly

Off-by-One Error

```
int counter = 1;
while (counter <= 10)
{                          // Executes 10 passes
   <do something>
   counter++;
}
```

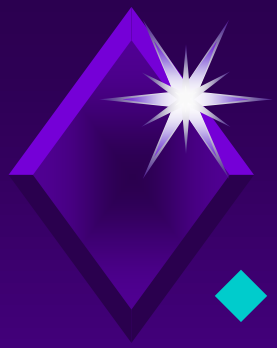
```
int counter = 1;
while (counter < 10)
{                          // Executes 9 passes
   <do something>
   counter++;
}
```

Infinite Loop

```
int counter = 1;
while (counter <= 10)
{                                  // Executes 5 passes
   <do something>
   counter = counter + 2;
}

int counter = 1;
while (counter != 10)
{                                  // Runs forever
   <do something>
   counter = counter + 2;
}
```

In general, avoid using **!=** in loop termination conditions.



Testing Loops

- Can vary the limit or the control variable, or both
- Use a negative value, zero, and a positive value
- Display an output trace if things aren’t working

Error Trapping

```
//”primed” while loop
cout<<"Enter a score between  ”<<low_double<<“ and  “<<high_double;
cin>>score;
while((score < low_double) || (score > high_double))
{
    cout<<“Invalid score, try again.”;

    //update the value to be tested in the Boolean Expression

     cout<<"Enter a score between  ”<<low_double<<“ and
    “<<high_double;
     cin>>score;
}
```

Nested Loops

- Nested loop
  - when a loop is one of the statements within the body of another loop.

```
for (k=1; k<=5; ++k)
   for (j=1; j<=3; ++j)
      cout<<(k+j)<<endl;
```

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  - Each loop needs to have its own level of indenting.
  - Use comments to explain each loop
  - Blank lines around each loop can make it easier to read

Repetition and Selection

- The use of an if statement within a loop to look for a certain condition in each iteration of the loop.
  - Examples:
    - to generate a list of Pythagorean Triples
    - to perform a calculation for each employee
    - to find prime numbers
      - let's look at our Case Study program for Chapter 6

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Loop Verification

- Loop verification
  - making sure that the loop performs its intended job.
- Input assertions
  - preconditions stating what is true before the loop is executed
- Output assertions
  - post conditions stating what is true after the loop is executed

Invariant and variant assertions

- Loop Invariant
  - states a relationship among variables that remains the same throughout all repetitions of the loop.
  - A statement that is true both:
    - before the loop is entered, and
    - after each iteration of the loop
- Loop Variant
  - an assertion that changes between the first and last iterations of the loop
  - should be stated in a way that guarantees that the loop is exited.
  - Should address the loop variable being incremented or decremented