A *loop* is the only control-flow construct that lets you *go back to an earlier point in the code*. Loops are designed to allow us to *iterate*—to execute the same piece of code over and over again.

We'll consider three different kinds of loops

While Loops

A `while` loop is created by a `while` statement. Its formal syntax is:

while statement :

Form:
while (Boolean Expression) $Statement_B$

Example:

```
cin >> grade;
while (grade > 100){
    cout << "Grade can't exceed 100!";
    cin >> grade;
}
```

Interpretation: A `grade` is entered and so long as its value exceeds `100` an error prompt is given and the `grade` is re-entered

As always $Statement_B$ can either be a *single statement* or a *statement block*.

We use the B subscript because its often called *the body of the loop*.

The control flow for the example in the syntax definition looks like this.

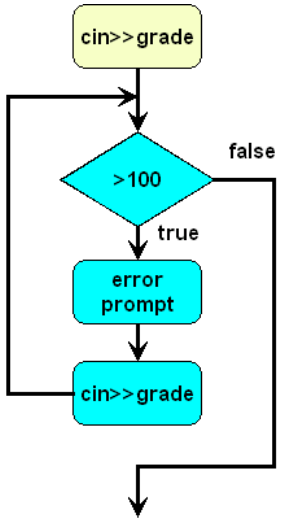
The `>100` in the decision block is short for `grade > 100` of the example

That boolean expression represents a *loop continuation condition*

If the condition is `true` the *body of the loop* is executed.

After the body is executed, we go back and test the *loop continuation condition* again

As soon as the condition is false, *the flow of control* moves to the statement immediately after the loop.



Here we use the `while` loop to generate a conversion table from degrees centigrade to degrees fahrenheit.

RUN VIDEO while_1.cpp

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

/*********** a while loop ***************

  Using a loop to generate a conversion table
  between degrees C and degrees F.

*****************************************/

int main(){
    int tempC = 0;

    cout << "A temperature conversion table\n\n";
    cout << "centigrade\tfahrenheit\n";
    cout << "-------------------------------------\n";

    while (tempC <= 100) {
        cout << "    " << tempC << "\t\t\t";

        cout << (9*tempC )/5 + 32 << '\n';

        tempC += 5;
```

```
    }

    cout << "-----------------------------------\n";
    return 0;
}
```

Loop Categories

There are a number of well-recognized loop categories, some of which we outline here

Count-Controlled Loops

When you know how many times to iterate.


sum.cpp

```
int main() {
  double sum = 0.0; // Accumulator for sum of values
  double val;       // Value input by user
  int num = 0;      // Number of values to sum
  int count = 0;    // Number of values input so far

  cout << "This program calculates the sum of the values entered.\n";
  cout << "How many values will you sum:";
  cin >> num;
  while (count < num) {
    cout << "Please enter a value: ";
    cin >> val;
    sum = sum + val;
    count++;
  }
  cout << "The sum is: " << sum << endl;

  return 0;
}
```

Note that the first example (temperature conversion) is basically a variation on this theme.

Event-Controlled Loops

Iteration continues until some event occurs in the body of the loop. Here's an example:


sum1.cpp

```
int main() {
  double sum = 0.0; // Accumulator for sum of values
  char ans = 'y';   // Answer from user
  double val;       // Value input by user

  cout << "This program calculates the sum of the values entered.\n";
```



```
  while (ans == 'y') {
    cout << "Please enter a value: ";
    cin >> val;
    sum = sum + val;
    cout << "Do you want to add another value? (Enter y or n) ";
    cin >> ans;
  }
  cout << "The sum is: " << sum << endl;

  return 0;
}
```

In this case, the event is a *decision by the user* to stop entering numbers.

Sentinel-Controlled Loops

- The termination condition is a special value read from input.
- The special value is called a sentinel or trailer value .
- The sentinel must not be a valid input value.

```
    cin >> x; // read first value
    while (x != -1) { // loop until sentinel value is read.
        // process x
        cin >> x; // get the next value
    }
```

Alternative (use side-effects and shortcut evaluation):

```
    while (cin >> x && x != -1) { // -1 is sentinel
         // process  x
    }
```


average.cpp

```
int main() {
  double sum = 0.0; // Accumulator for sum of values
  int count = 0;    // Counter for number of values
  double val;       // Value input by user
  double avg;       // Average of values

  cout << "This program calculates the average of a sequence of" << endl;
  cout << "positive values.\n";
  cout << "Please enter the values (enter a negative value to exit): ";
  cin >> val;
  while (val > 0) {
    sum = sum + val;
    count++;
    cin >> val;
  }
  if (count > 0) {
    avg = sum / double(count);
    cout << "The average is: " << avg << endl;
  } else {
    cout << "No values were entered.\n";
```

```
  }

  return 0;
}
```

Flag-Controlled Loops

flag—A Boolean variable used to control logical flow.

```
bool positive = true; // flag, set to false when x < 0.
while (positive) {
    cin >> x; // ...
    if (x < 0) {
        positive = false;
    }
}
```

For Loops

The `for` statement is particularly well suited for count-controlled loops.

The formal syntax for the `for` loop is

for statement :

Form:
for (init expression ;
boolean expression ;
update expression)
$Statement_B$

Example:

```
for (int i = 0; i < 7; i++)
    cout << i * i;
```

Interpretation: An `int i` is declared for the duration of the loop and its value initialised to `0`. i^2 is output in the body of the loop and then `i` is incremented. This continues until `i` is `7`.

Again $Statement_B$ is called *the body of the loop* and it can either be a *single statement* or a *statement block*.

Here's an example of a program that uses the `for` loop to create a table of factorials.

for_loop.cpp

```
/*******  for loop demonstration ********
    A little program to output a table
    of factorials

NOTE: The for statement's style is a little unusual
   it would normally be written out on one line
   for (int i = 0; i < 10; i++)

   I've done it this way to focus on the three
   separate expressions in the statement.

*****************************************/

#include <iostream>
using namespace std;    // cout is in the std namespace

int main(){
    int factorial = 1;

// Output a table heading
    cout << "Table of Factorials\n  i\t  i!\n\n";


    for (int i = 0;
            i < 10;
                i++)  {
        if (i !=0)
            factorial *= i;
        cout << i << "\t" << factorial << '\n';
    }

    cout << "That's all folks!\n";
    return 0;
}
```

Please note that in both the syntax definition block and the example the three internal expressions in the for loop have been written on separate lines.

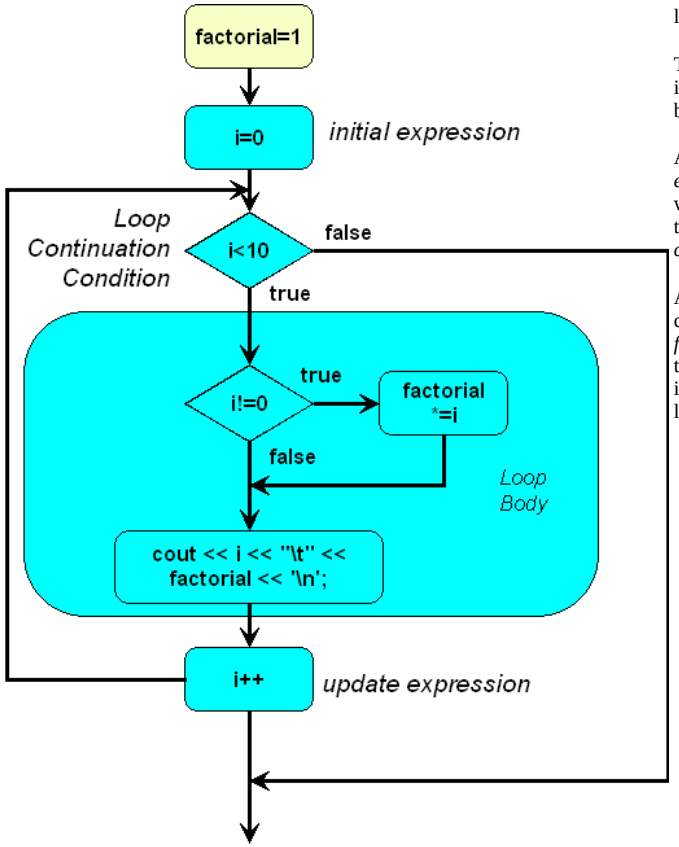
This is not normal.

```
 for (int i = 0; i < 10; i++) {
```

would be the normal way of starting the `for` loop

The *initial expression* is executed **once**, before anything else in the `for` loop.

The *loop continuation condition* is executed **before** the body of the



loop.

The *update expression* is executed **after** the body of the loop

After the *update expression* is executed, we go back and test the *loop continuation condition* again

As soon as the condition is false, *the flow of control* moves to the statement immediately after the loop.

Loop Design

1. The general case:
   - What should be done in the body?
2. The special cases:

- Under what condition should the iteration stop?
- How should the loop control condition be initialized?
- How should the loop control condition be updated?
- How should other variables be initialized?
- How should other variables be updated?
- What is the state when the loop exits?

Notice we have put the general case first. Although it may seem counter-intuitive (because when you read the code the `while` or the `for` precedes the body of the loop)

Design loops from the inside out (from the general to the specific).

Note the implication here is that

1. first design the loop, then
2. code the loop

Pseudo Code

How can we design before we code?

Enter *pseudo code*, which we will introduce by example.

Let's consider a program to compute the mark for every student in a course. Here's an algorithm specified in pseudo code

---

enter the number of students in the course

enter the midterm1, midterm2, assignments, labs and final max (or 0 if none) and percentage

set student to 1

while student <= students

    enter mark for each component

    compute course mark

    increment student

Now consider the problem of entering a mark for each component. There's a lot to that. As before, we need to *refine* this step.

enter mark for a component--->

    if max of component > 0

        prompt for mark

        enter mark

        while mark > max or < 0

            give error prompt

enter mark

Pseudo code is just a refinement of the way we taught functional decomposition.

In pseudo code, we use the control structures of computer programming but we state what we want to do in plain english or using any convenient, understandable notation (e.g. mathematical).

The idea is to get the control structures right.

Let's take the pseudo code and use it to produce a program.

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