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</tr>
</tbody>
</table>
#include <stdio.h>
#include <stdlib.h>

int main ()
{
    const float minimum_energy = 0;
    const int program_success_code = 0;
    const int program_failure_code = -1;
    float energy_in_gallons_of_gasoline;
}
while Loop Example #2

printf("What is the energy in gallons of gasoline?\n");
scanf("%f", &energy_in_gallons_of_gasoline);
while (energy_in_gallons_of_gasoline < 
    minimum_energy) {
    printf("ERROR: you can't have a");
    printf(" negative energy %f!\n");
    printf("So really, what is the");
    printf(" energy in gallons of gasoline?\n");
    scanf("%f", &energy_in_gallons_of_gasoline);
} /* while (energy_in_gallons_of_gasoline < ...) */
printf("The energy in gallons of gasoline is valid.\n");
return program_success_code;
} /* main */
while Loop Example #3

% gcc -o energy_idiot_while energy_idiot_while.c
% energy_idiot_while
What is the energy in gallons of gasoline? -5
ERROR: you can't have a negative energy!
So really, what is the energy in gallons of gasoline? -4
ERROR: you can't have a negative energy!
So really, what is the energy in gallons of gasoline? 0
The energy in gallons of gasoline is valid.
Repetition and Looping

*Repetition* means performing the same set of statements over and over.

The most common way to perform repetition is via *looping*. A *loop* is a sequence of statements to be executed, in order, over and over, as long as some condition continues to be true.
C has a loop construct known as a **while** loop:

```c
while (condition) {
    statement1;
    statement2;
    ...
}
```

The condition of a **while** loop is a Boolean expression completely enclosed in parentheses – just like the condition of an **if** block.

The sequence of statements between the **while** statement’s block open and block close is known as the **loop body**.

**while** Loop
while Loop Behavior

```java
while (condition) {
    statement1;
    statement2;
    ...
}
```

A while loop has to the following behavior:

1. The condition is evaluated, resulting in a value of either true (1) or false (0).
2. If the condition evaluates to false (0), then the statements inside the loop body are skipped, and control is passed to the statement that is immediately after the while loop’s block close.
3. If the condition evaluates to true (1), then:
   a. the statements inside the loop body are executed in sequence.
   b. When the while loop’s block close is encountered, the program jumps back up to the associated while statement and starts over with Step 1.
while Loop vs. if Block

A while loop is SIMILAR to an if block, EXCEPT:

1. UNLIKE an if block, the keyword is while.

2. UNLIKE an if block, when a while loop gets to its block close, it jumps back up to the associated while statement.

3. UNLIKE an if block, a while loop has EXACTLY ONE clause, which is analogous to the if clause. A while loop CANNOT have anything analogous to an elseif clause nor to an else clause.
while Loop Flowchart

statement_before;
while (condition) {
    statement_inside1;
    statement_inside2;
    ...
}
statement_after;
#include <stdio.h>
#include <stdlib.h>

int main ()
{
    const float minimum_energy = 0;
    const int program_success_code = 0;
    const int program_failure_code = -1;
    float energy_in_gallons_of_gasoline;
}
while Loop Example #2

```c
printf("What is the energy in gallons of gasoline?\n");
scanf("%f", &energy_in_gallons_of_gasoline);
while (energy_in_gallons_of_gasoline < minimum_energy) {
    printf("ERROR: you can't have a negative energy!\n");
    printf("So really, what is the ");
    printf(" energy in gallons of gasoline?\n");
    scanf("%f", &energy_in_gallons_of_gasoline);
} /* while (energy_in_gallons_of_gasoline < ...) */
printf("The energy in gallons of gasoline is valid.\n");
return program_success_code;
} /* main */
```
% gcc -o energy_idiot_while energy_idiot_while.c
% energy_idiot_while

What is the energy in gallons of gasoline?
-5
ERROR: you can't have a negative energy!
So really, what is the energy in gallons of gasoline?
-4
ERROR: you can't have a negative energy!
So really, what is the energy in gallons of gasoline?
0
The energy in gallons of gasoline is valid.
while Loop Example Flowchart

```c
printf("What is the energy in gallons of gasoline?\n");
scanf("%f", &energy_in_gallons_of_gasoline);
while (energy_in_gallons_of_gasoline <
    minimum_energy) {  
    printf("ERROR: you can't have a");
    printf(" negative energy!\n");
    printf("So really, what is the");
    printf(" energy in gallons of gasoline?\n");
    scanf("%f", &energy_in_gallons_of_gasoline);
} /* while (energy_in_gallons_of_gasoline < ...) */
printf("the energy in gallons of gasoline is valid.\n");
```

- **Prompt for energy.**
  - **Input energy.**
    - **energy < 0**
      - **False**
        - **Output error.**
        - **Prompt again.**
          - **Input energy again.**
        - **Output valid.**
      - **True**
Execute Body How Many Times?

while (condition) {
    statement1;
    statement2;
    ...  
}

If the condition evaluates to false (0), then the loop body won’t be executed at all (that is, zero times).

If the condition evaluates to true (1), then the loop body may be executed at least one more time.
An Infinite Loop #1

An **infinite loop** is a loop whose condition never evaluates to false.

```c
#include <stdio.h>

int main ()
{ /* main */
    const int computers_number = 5;
    const int program_success_code = 0;
    int users_number;

    printf("Enter an integer: \n");
    scanf("%d", &users_number);
    printf("I had %d. \n", computers_number);
    while (users_number < computers_number) {
        printf("Your number is less than mine! \n");
    } /* while (users_number < computers_number) */
    return program_success_code;
} /* main */
```
An Infinite Loop #2

```bash
% gcc -o infiniteloop infiniteloop.c
% infiniteloop
Enter an integer:
6
I had 5.
% infiniteloop
Enter an integer:
5
I had 5.
% infiniteloop
Enter an integer:
4
I had 5.
Your number is less than mine!
Your number is less than mine!
Your number is less than mine!
Your number is less than mine!
Your number is less than mine!
Your number is less than mine!
Your number is less than mine!
Your number is less than mine!
Your number is less than mine!
Your number is less than mine!
...
Aside: How to Kill a Program in Unix

On most Unix systems, including ssh.ou.edu, you can quit out of a program that is currently executing by typing:

Ctrl - C
Kinds of Statements Inside \texttt{while} Loop

Between the \texttt{while} statement’s block open and its associated block close, there can be \textbf{any kind} of \textbf{executable} statements, and \textbf{any number} of them.

For example:
\begin{itemize}
  \item \texttt{printf} statements;
  \item \texttt{scanf} statements;
  \item assignment statements;
  \item \texttt{if} blocks;
  \item \texttt{while} loops.
\end{itemize}

There are several other kinds of executable statements that can occur inside a \texttt{while} loop, some of which we’ll learn later in the semester.
In the event that the `while` condition evaluates to true (1), then the statements inside the `while` loop body will be executed one by one, in the order in which they appear in the `while` loop.
No Declarations Inside while Loop

Notice that a while loop **SHOULDN’T** contain declaration statements, because the while statement is an executable statement, and ALL declarations **MUST** come before ANY executable statements.
A compound statement is a sequence of statements, with a well-defined beginning and a well-defined end, to be executed, in order, under certain circumstances.

A while loop is a compound statement, just like an if block. We’ll see others later.

Although a while loop is actually a sequence of statements, we can treat it as a single “super” statement in some contexts.

Compound statements are also known as blocks.
Compound Statement a.k.a. Block #2

In C, a compound statement, also known as a block, is delimited by curly braces.
That is, a compound statement/block begins with a block open

```c
{
```
and ends with a block close

```c
}
```
Another while Loop Example #1

#include <stdio.h>

int main ()
{ /* main */
    const int false = 0;
    const int true = 1;
    const int minimum_number = 1;
    const int maximum_number = 100;
    const int computers_number = 32;
    const int close_distance = 5;
    const int very_close_distance = 1;
    const int negative_distance = -1;
    const int no_distance = 0;
    const int program_success_code = 0;
    int users_number, users_distance;
    int users_last_distance = negative_distance;
    char correct_number_hasnt_been_input = true;
Another while Loop Example #2

printf("I'm thinking of a number between %d and %d.\n", minimum_number, maximum_number);
while (correct_number_hasnt_been_input) {
    printf("What number am I thinking of?\n");
    scanf("%d", &users_number);
    if ((users_number < minimum_number) ||
        (users_number > maximum_number)) {
        printf("Hey! That's not between %d and %d!\n", minimum_number, maximum_number);
        printf("I'll pretend you didn’t say that.\n");
    } /* if ((users_number < minimum_number) || ...) */
    else if (users_number == computers_number) {
        printf("That's amazing!\n");
        correct_number_hasnt_been_input = false;
    } /* if (users_number == computers_number) */
Another while Loop Example #3

```c
else {
    users_distance =
        abs(users_number - computers_number);
    if (users_distance == very_close_distance) {
        printf("You're incredibly hot!\n");
    } /* if (users_distance == very_close_distance) */
    else if (users_last_distance < no_distance) {
        printf("Not bad for your first try.\n");
    } /* if (users_last_distance < no_distance) */
    else if (users_distance < users_last_distance) {
        printf("You're getting warmer ...\n");
    } /* if (users_distance < users_last_distance) */
    else if (users_distance > users_last_distance) {
        printf("Ouch! You're getting colder.\n");
    } /* if (users_distance > users_last_distance) */
    else {
        printf("Uh oh. You made no progress.\n");
    } /* if (users_distance > ...)...else */
    users_last_distance = users_distance;
} /* if (users_number == computers_number)...else */
/* while (correct_number_hasnt_been_input) */
printf("Good for you!\n");
return program_success_code;
} /* main */
```
Another while Loop Example #4

```
% gcc -o warmercolder warmercolder.c
% warmercolder
I'm thinking of a number between 1 and 100.
What number am I thinking of? 0
Hey! That's not between 1 and 100!
I'll pretend you didn't say that.
What number am I thinking of? 101
Hey! That's not between 1 and 100!
I'll pretend you didn't say that.
What number am I thinking of? 50
Not bad for your first try.
What number am I thinking of? 40
You're getting warmer ....
What number am I thinking of? 60
Ouch! You're getting colder.
```
Another while Loop Example #5

What number am I thinking of?
30
You're getting warmer ....
What number am I thinking of?
35
Ouch! You're getting colder.
What number am I thinking of?
33
You're incredibly hot!
What number am I thinking of?
31
You're incredibly hot!
What number am I thinking of?
32
That's amazing!
Good for you!
Yet Another while Loop Example #1

```c
#include <stdio.h>
#include <stdlib.h>
int main ()
{ /* main */
  const int initial_sum = 0;
  const int increment = 1;
  const int program_success_code = 0;
  const int program_failure_code = -1;
  int initial_value, final_value;
  int count;
  int sum;
```
Yet Another while Loop Example #2

```c
printf("What value would you like to ");
printf("start counting at?
");
scanf("%d", &initial_value);
printf("What value would you like to ");
printf("stop counting at,
");
printf(" which must be greater than ");
printf("or equal to %d
", initial_value);
scanf("%d", &final_value);
if (final_value < initial_value) {
    printf("ERROR: the final value %d is less
", final_value);
    printf(" than the initial value %d.\n", initial_value);
    exit(program_failure_code);
} /* if (final_value < initial_value) */
```
Yet Another while Loop Example #3

```c
sum   = initial_sum;
count = initial_value;
while (count <= final_value) {
    sum = sum + count;
    count = count + increment;
} /* while (count <= final_value) */
printf("The sum of the integers from");
printf(" %d through %d is %d.\n", initial_value, final_value, sum);
return program_success_code;
} /* main */
```
Yet Another while Loop Example #4

% gcc -o whilecount whilecount.c
% whilecount
What value would you like to start counting at? 1
What value would you like to stop counting at, which must be greater than or equal to 1? 0
ERROR: the final value 0 is less than the initial value 1.
% whilecount
What value would you like to start counting at? 1
What value would you like to stop counting at, which must be greater than or equal to 1? 5
The sum of the integers from 1 through 5 is 15.
The **state** of a program is the set of values of all of its variables at a given moment during execution; that is, it’s a **snapshot** of the memory that’s being used.

The state also includes information about **where you are** in the program when that snapshot is taken.

A **trace** of a program is a listing of the state of the program after each statement is executed.

Tracing helps us to examine the behavior of a piece of code, and so it sometimes can be useful in debugging.
States & Traces #2

Suppose that, in the previous example program, the user input 1 for initial_value and 5 for final_value.

Let’s examine the program fragment around the loop.

```c
sum   = initial_sum;
count = initial_value;
while (count <= final_value) {
    sum = sum + count;
    count = count + increment;
} /* while (count <= final_value) */
```
States & Traces #3

sum   = initial_sum;
count = initial_value;
while (count <= final_value) {
    sum = sum + count;
count = count + increment;
} /* while (count <= final_value) */

If we number these statements, we get:

1   sum   = initial_sum;
2   count = initial_value;
3   while (count <= final_value) {
    4       sum = sum + count;
    5       count = count + increment;
} /* while (count <= final_value) */
while Loop Lesson
CS1313 Fall 2020

## Tracing the Loop #1

```c
1   sum   = initial_sum;
2   count = initial_value;
3   while (count <= final_value) {
4       sum = sum + count;
5       count = count + increment;
6   } /* while (count <= final_value) */
```

<table>
<thead>
<tr>
<th>Snapshot of Iteration #</th>
<th>After stmt #</th>
<th>Trace Value of sum</th>
<th>Trace Value of count</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>N/A</td>
<td>1</td>
<td>0</td>
<td>garbage</td>
<td>Haven’t entered loop yet</td>
</tr>
<tr>
<td>N/A</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>Haven’t entered loop yet</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>0</td>
<td>1</td>
<td>Condition evaluates to true (1)</td>
</tr>
<tr>
<td>1</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>new sum = old sum + count = 0 + 1 = 1</td>
</tr>
<tr>
<td>1</td>
<td>5</td>
<td>1</td>
<td>2</td>
<td>new count = old count + 1 = 1 + 1 = 2</td>
</tr>
<tr>
<td>1</td>
<td>6</td>
<td>1</td>
<td>2</td>
<td>Jump back up to stmt #3 to start iteration #2</td>
</tr>
</tbody>
</table>
Tracing the Loop #2

1   sum   = initial_sum;
2   count = initial_value;
3   while (count <= final_value) {
4       sum = sum + count;
5       count = count + increment;
6   } /* while (count <= final_value) */

<table>
<thead>
<tr>
<th>Iteration #</th>
<th>After stmt #</th>
<th>Value of sum</th>
<th>Value of count</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>Condition evaluates to true (1)</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>new sum = old sum + count = 1 + 2 = 3</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>new count = old count + 1 = 2 + 1 = 3</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td>3</td>
<td>3</td>
<td>Jump back up to stmt #3 to start iteration #3</td>
</tr>
</tbody>
</table>
Tracing the Loop #3

1   sum   = initial_sum;
2   count = initial_value;
3   while (count <= final_value) {
4       sum = sum + count;
5       count = count + increment;
6   } /* while (count <= final_value) */

<table>
<thead>
<tr>
<th>Iteration #</th>
<th>After stmt #</th>
<th>Value of sum</th>
<th>Value of count</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>Condition evaluates to true (1)</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>6</td>
<td>3</td>
<td>new (\text{sum} = \text{old sum} + \text{count} = 3 + 3 = 6)</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>6</td>
<td>4</td>
<td>new (\text{count} = \text{old count} + 1 = 3 + 1 = 3)</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td>6</td>
<td>4</td>
<td>Jump back up to stmt #3 to start iteration #4</td>
</tr>
</tbody>
</table>
### Tracing the Loop #4

```plaintext
1   sum   = initial_sum;
2   count = initial_value;
3   while (count <= final_value) {
4       sum = sum + count;
5       count = count + increment;
6   } /* while (count <= final_value) */
```

<table>
<thead>
<tr>
<th>Iteration #</th>
<th>After stmt #</th>
<th>Value of sum</th>
<th>Value of count</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>3</td>
<td>6</td>
<td>4</td>
<td>Condition evaluates to true (1)</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>10</td>
<td>4</td>
<td>new sum = old sum + count = 6 + 4 = 10</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>10</td>
<td>5</td>
<td>new count = old count + 1 = 4 + 1 = 5</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
<td>10</td>
<td>5</td>
<td>Jump back up to stmt #3 to start iteration #5</td>
</tr>
</tbody>
</table>
Tracing the Loop #5

```c
1   sum   = initial_sum;
2   count = initial_value;
3   while (count <= final_value) {
4       sum = sum + count;
5       count = count + increment;
6   } /* while (count <= final_value) */
```

<table>
<thead>
<tr>
<th>Iteration #</th>
<th>After stmt #</th>
<th>Value of sum</th>
<th>Value of count</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>3</td>
<td>10</td>
<td>5</td>
<td>Condition evaluates to true (1)</td>
</tr>
<tr>
<td>5</td>
<td>4</td>
<td>15</td>
<td>5</td>
<td><strong>new</strong> sum = <strong>old</strong> sum + count = 10 + 5 = 15</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>15</td>
<td>6</td>
<td><strong>new</strong> count = <strong>old</strong> count + 1 = 5 + 1 = 6</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
<td>15</td>
<td>6</td>
<td>Jump back up to stmt #3 to start iteration #6</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
<td>15</td>
<td>6</td>
<td>Condition evaluates to false (0), loop exited</td>
</tr>
</tbody>
</table>