Boolean Data Lesson #1 Outline

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Data Types

A **data type** is (surprise) a type of data:

- **Numeric**
  - `int`: *integer*
  - `float`: *floating point* (also known as *real*)

- **Non-numeric**
  - `char`: *character*

```c
#include <stdio.h>
int main ()
{ /* main */
    float standard_deviation, relative_humidity;
    int count, number_of_silly_people;
    char middle_initial, hometown[30];
} /* main */
```
C Boolean Data Type: \texttt{char} or \texttt{int}

The C data type typically used for storing Boolean values is \texttt{char}, although \texttt{int} will also work. Like numeric data types, Booleans have particular ways of being stored in memory and of being operated on. Conceptually, a Boolean value represents a single bit in memory.

But, the \texttt{char} and \texttt{int} data types aren’t implemented this way – if for no other reason than that computers can’t address a single bit, since the smallest collection of bits that they can address is a byte (or, in a few cases, a word).
C also has a built-in data type for Booleans:

    bool

The `bool` data type has possible values

    false

and

    true

However, some C compilers don’t have the `bool` data type and the Boolean values `true` and `false` available by default; you have to make them available using this directive:

```
#include <stdbool.h>
```

(after `#include <stdio.h>`).
bool Data Type: Not Used in CS1313

In CS1313, we WON’T use the bool data type, nor its values true and false. Instead, we’ll use char or int. Similarly, we’ll use 0 for falsity and 1 (or any nonzero integer value) for truth.
Boolean Declaration

```c
char CS1313_lectures_are_fascinating;
```

This declaration tells the compiler to grab a group of bytes, name them `CS1313_lectures_are_fascinating`, and think of them as storing a Boolean value (either `true` or `false`).

**How many bytes?**

Even though conceptually a Boolean represents a single bit, in practice `char` variables are usually implemented using 8 bits (1 byte):

`CS1313_lectures_are_fascinating` : 

```
[ ][ ][ ][ ][ ][ ][ ][ ]
```
**Boolean or Character?**

**Question:** How does the C compiler know that a particular `char` declaration is a Boolean rather than a character?

**Answer:** It doesn’t.

Whether a `char` (or an `int`) is treated by a program as a Boolean or a character (respectively, an integer) depends entirely on how you use it in the program.
Boolean or Character Example #1

```c
#include <stdio.h>

int main ()
{ /* main */
    const int maximum_short_height_in_cm = 170;
    const int program_success_code = 0;
    int my_height_in_cm = 160;
    char I_am_Henry = 1;
    char I_am_tall;
    char my_middle_initial = 'J';

    I_am_tall = 
        (!I_am_Henry) &&
        (my_height_in_cm >
        maximum_short_height_in_cm);
    printf("I_am_Henry = %d\n", I_am_Henry);
    printf("my_height_in_cm = %d\n",
            my_height_in_cm);
    printf("I_am_tall = %d\n", I_am_tall);
    printf("my_middle_initial = %c\n",
            my_middle_initial);
    return program_success_code;
} /* main */
```
Boolean or Character Example #2

```c
% gcc -o short short.c
% short
I_am_Henry = 1
my_height_in_cm = 160
I_am_tall = 0
my_middle_initial = J
```

Whether a `char` (or an `int`) is treated by a program as a Boolean or a character (respectively, an integer) depends entirely on how you use it in the program.
Boolean, Character or Integer? #1

In the previous example program, we had char variables named I_am_Henry and I_am_tall.

We treated them as Boolean variables in the calculation subsection, but in the output subsection we had:

```c
printf("I_am_Henry = %d\n", I_am_Henry);
printf("I_am_tall = %d\n", I_am_tall);
```

How can this be?
Boolean, Character or Integer? #1

```c
char I_am_Henry = 1;
char I_am_tall;
...
I_am_tall = (!I_am_Henry) && ... ;
...
printf("I_am_Henry = %d\n", I_am_Henry);
...
printf("I_am_tall = %d\n", I_am_tall);
```

How can it be that the same variable is simultaneously a Boolean, a character and an integer?

It turns out that `char` not only means character, it also means an integer of 1 byte (8 bits).

This is confusing, but you’ll get used to it.
Boolean Literal Constants

In C, a *Boolean literal constant* can have either of two possible values (but not both at the same time, of course):

- to represent *false*: 0
- to represent *true*: anything other than 0 (usually 1)
Using Boolean Literal Constants #1

We can use Boolean literal constants in several ways:

- In declaring and initializing a **named constant**:
  
  ```c
  const char true = 1;
  ```

- In declaring and initializing a **variable**:
  
  ```c
  char I_am_getting_a_bad_grade = 0;
  ```

- In an **assignment**:
  
  ```c
  this_is_my_first_guess = 1;
  ```

- In an **expression**:
  
  ```c
  Henry_is_tall && 1;
  ```
Using Boolean Literal Constants #2

The first two of these uses – in a named constant declaration and in a variable declaration – are considered good programming practice, **AND SO IS THE THIRD** (in an assignment), which is a way that **Booleans are different from numeric data**. As for using Boolean literal constants in expressions, it’s not so much that it’s considered bad programming practice, it’s just that it’s kind of pointless.
What is a Boolean Expression? #1

a || (b || c && !d) && e && (f || g) && h

In programming, a **Boolean expression** is a combination of:

- **Boolean Operands**
- **Boolean Operators**
- **Parentheses**: ( )
What is a Boolean Expression? #2

In programming, a **Boolean expression** is a combination of:

- **Boolean Operands**, such as:
  - Boolean literal constants (0 for **false**, nonzero for **true**)
  - Boolean named constants
  - Boolean variables
  - **Boolean-valued function invocations**

- **Boolean Operators**
- **Parentheses**: (  )

```
a || (b || c && !d) && e && (f || g) && h
```
What is a Boolean Expression? #3

In programming, a **Boolean expression** is a combination of:

- **Boolean Operands**
- **Boolean Operators**, such as:
  - Relational Operators (which have **numeric operands**)
  - Logical Operators
- **Parentheses**: (  )
What is a Boolean Expression? #4

In programming, a **Boolean expression** is a combination of:

- **Boolean Operands**
- **Boolean Operators**, such as:
  - Relational Operators (which have **numeric operands**)
    - Equal: `==`
    - Not Equal: `!=`
    - Less Than: `<`
    - Less Than or Equal To: `<=`
    - Greater Than: `>`
    - Greater Than or Equal To: `>=`
  - Logical Operators
  - **Parentheses**: `()`
What is a Boolean Expression? #5

In programming, a **Boolean expression** is a combination of:

- **Boolean Operands**
- **Boolean Operators**, such as:
  - Relational Operators (which have numeric operands)
  - Logical Operators
    - **Negation** (NOT): !
    - **Conjunction** (AND): &&
    - **Disjunction** (OR): ||
- Parentheses: ()
Boolean Expressions

Just like a numeric (arithmetic) expression, a **Boolean expression** is a combination of Boolean terms (such as variables, named constants, literal constants and Boolean-valued function calls), Boolean operators (for example, !, &&, ||, relational comparisons) and parentheses.

\[
\begin{align*}
\text{I}_\text{am}_\text{happy} & \\
!\text{I}_\text{am}_\text{happy} & \\
\text{it}_\text{is}_\text{raining} & \land \text{it}_\text{is}_\text{cold} & \\
\text{it}_\text{is}_\text{raining} & \lor \text{it}_\text{is}_\text{cold} & \\
(!\text{it}_\text{is}_\text{raining}) & \lor (\text{it}_\text{is}_\text{cold} \land \text{I}_\text{am}_\text{happy}) & \\
\end{align*}
\]
Like arithmetic operations, Boolean operations come in two varieties: *unary* and *binary*.

A unary operation is an operation that uses only one term; a binary operation uses two terms.

Boolean operations include:

<table>
<thead>
<tr>
<th>Operation</th>
<th>Kind</th>
<th>Operator</th>
<th>Usage</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identity</td>
<td>Unary</td>
<td>None</td>
<td>$x$</td>
<td>No change to value of $x$</td>
</tr>
<tr>
<td>Negation</td>
<td>Unary</td>
<td>!</td>
<td>$!x$</td>
<td>Inverts value of $x$</td>
</tr>
<tr>
<td>Conjunction (AND)</td>
<td>Binary</td>
<td>&amp;&amp;</td>
<td>$x$ &amp;&amp; $y$</td>
<td>1 if both $x$ is nonzero AND $y$ is nonzero; otherwise 0</td>
</tr>
<tr>
<td>Disjunction (Inclusive OR)</td>
<td>Binary</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
C Boolean expressions evaluate to either:

- 0 (representing **false**)
- 1 (representing **true**)

Note that **any nonzero value represents true**, but, when C evaluates a Boolean expression, then if that expression evaluates to true, then specifically its value is 1.

Note that **only 0 represents false, ever.**
Boolean Data Lesson #1

#include <stdio.h>

int main ()
{ /* main */
  const char true = 1, false = 0;

  printf(" true = %d,  false = %d\n",  true,  false);
  printf("!true = %d, !false = %d\n", !true, !false);
  printf("\n");
  printf("true  || true  = %d\n", true  || true);
  printf("true  || false = %d\n", true  || false);
  printf("false || true  = %d\n", false || true);
  printf("false || false = %d\n", false || false);

  printf("\n");
  printf("true  && true  = %d\n", true  && true);
  printf("true  && false = %d\n", true  && false);
  printf("false && true  = %d\n", false && true);
  printf("false && false = %d\n", false && false);
}
/* main */
Boolean Expression Example #2

% gcc -o logic_expression_simple logic_expression_simple.c
% logic_expression_simple
  true = 1, false = 0
!true = 0, !false = 1

true || true = 1
true || false = 1
false || true = 1
false || false = 0

ture && true = 1
true && false = 0
false && true = 0
false && false = 0
Boolean Variables Example #1

```c
#include <stdio.h>

int main ()
{
    /* main */
    const int true = 1;
    const int false = 0;
    int project_due_soon;
    int been_putting_project_off;
    int start_working_on_project_today;

    printf("Is it true that you have a programming project due soon?\n");
    printf("  (Answer %d for true, %d for false.)\n", true, false);
    scanf("%d", &project_due_soon);
    printf("Is it true that you have been putting off working on it?\n");
    printf("  (Answer %d for true, %d for false.)\n", true, false);
    scanf("%d", &been_putting_project_off);
    start_working_on_project_today =
        project_due_soon && been_putting_project_off;
    printf("Is it true that you should start ");
    printf("working on it today?\n");
    printf("ANSWER: %d\n",
        start_working_on_project_today);
} /* main */
```
Boolean Variables Example #2

% gcc -o pp_logic pp_logic.c
% pp_logic
Is it true that you have a programming project due soon?
   (Answer 1 for true, 0 for false.)
   1
Is it true that you have been putting off working on it?
   (Answer 1 for true, 0 for false.)
   1
Is it true that you should start working on it today?
ANSWER: 1