Boolean Data Lesson #1 Outline

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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 ()
{
    float standard_deviation, relative_humidity;
    int count, number_of_silly_people;
    char middle_initial, hometown[30];
}
```

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, because 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:

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

(after `#include <stdio.h>`).
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.
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 :
```

**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 as a character (respectively, an integer) depends entirely on how you use it in the program.
#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

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)
We can use Boolean literal constants in several ways:

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

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

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

- In an **expression**:
  ```
  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

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: ( )
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? 

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

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 \textbf{Boolean expression} is a combination of Boolean terms (such as variables, named constants, literal constants and Boolean-valued function calls), Boolean operators (for example, $\neg$, $\&\&$, $\mid\mid$, relational comparisons) and parentheses.

\begin{align*}
\text{I\_am\_happy} \\
\neg\text{I\_am\_happy} \\
\text{it\_is\_raining} \&\& \text{it\_is\_cold} \\
\text{it\_is\_raining} \mid\mid \text{it\_is\_cold} \\
(\neg\text{it\_is\_raining}) \mid\mid (\text{it\_is\_cold} \&\& \text{I\_am\_happy})
\end{align*}
Boolean Operations

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 (AND)</td>
<td>Binary</td>
<td>&amp; &amp;</td>
<td>x &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.
#include <stdio.h>

int 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

```bash
% 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

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

```c
#include <stdio.h>

int 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