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*

Note that this list of data types ISN’T exhaustive – there are many more data types (and you can define your own).

```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: char or int

The C data type typically used for storing Boolean values is char, although int will also work.

Like numeric data types, Booleans have particular ways of being stored in memory and particular ways of being operated on.

Conceptually, a Boolean value represents a single bit in memory.

But, the char and 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 (8 bits) – or, in a few cases, a word.
C Built-In Boolean Data Type: \texttt{bool}

C also has a built-in data type for Booleans:

\begin{verbatim}
bool
\end{verbatim}

The \texttt{bool} data type has possible values

\begin{verbatim}
false
\end{verbatim}
and

\begin{verbatim}
true
\end{verbatim}

However, some C compilers don’t have available by default the \texttt{bool} data type nor the Boolean values \texttt{true} and \texttt{false}; you have to make them available using this directive:

\begin{verbatim}
#include <stdbool.h>
\end{verbatim}

(after \#include \texttt{<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 false and `1` (or any nonzero integer value) for true.
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):
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 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 */
% 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.
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", I_am_Henry);
printf("I_am_tall = %d\n", I_am_tall);
```

How can this be?
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**:  
  ```
  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_isnt_tall = Henry_is_tall && 0;
  ```
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**: (   )
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**: (  )

\[ a \lor (b \lor c \land \neg d) \land e \land (f \lor g) \land h \]
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**)
    - Is Equal: `==`
    - Not Equal: `!=`
    - Less Than: `<`
    - Less Than or Equal To: `<=`
    - Greater Than: `>`
    - Greater Than or Equal To: `>=`
  - Logical Operators
  - **Parentheses**: `()`

\[
a \lor (b \lor c \land \neg d) \land e \land (f \lor g) \land h
\]
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**: ( )

```
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```
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.

\[
\begin{align*}
    & I\_am\_happy \\
    & \neg I\_am\_happy \\
    & it\_is\_raining \land it\_is\_cold \\
    & it\_is\_raining \lor it\_is\_cold \\
    & (\neg it\_is\_raining) \lor (it\_is\_cold \land I\_am\_happy)
\end{align*}
\]
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</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>(x || y)</td>
<td>1 if either (x) is nonzero OR (y) is nonzero, or both; otherwise 0</td>
</tr>
</tbody>
</table>
C Boolean expressions evaluate to either:

- 0 (representing \textit{false})
- 1 (representing \textit{true})

Note that \textit{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 \textit{only 0 represents false}, ever.
#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
#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("Let's find out whether you should start working today!\n");
    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
Let's find out whether you should start working today!
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