CSCI 141

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The `bool` data type
Boolean Operators
Boolean Expressions

Goals

- Understand the use and values of the type `bool` and the meaning of a boolean expression.
- Understand the behavior of the arithmetic comparison operators: `>`, `<`, `<=`, `>=`, `==`, `!=`
- Understand the behavior of the boolean logical operators `and`, `or`, `not`
- Know where the above operators fit into the order of operations
- Be able to write out a truth table for a boolean expression of two variables.

What have we covered so far?

- Data is stored in memory.

  integers are stored using their *binary* representation

- Each piece of data has a type.

  so far we've seen: `int, float, str`

- Variables can assign names to pieces of data. **the assignment operator stores a value in a variable, as in:**

  ```
  my_var = "Hello, world!"
  ```

- Operators can do things to the data (these operations are performed by the CPU).

  so far: assignment operator (=)
  arithmetic operators: (`+,-,*,/,**,//,%`)

What have we covered so far?

- A function can take inputs (arguments) and can produce an output (return value)

  so far: `input, print, type, int, float, str`

- Statements are instructions that are executed

  so far: assignment statements, such as `my_var = 64 + 8`

- Expressions are like phrases that can be evaluated to determine what value they represent.

  so far:
  - **functions that return values, like `int(42.8)`**
  - **arithmetic expressions, like `(4 + 2) / 2`**
  - **and combinations of other expressions, like `(2**3) // int(user_input)`**

Some more familiar operators

<	Less than
>	Greater than
<=	Less than or equal to
>=	Greater than or equal to
==	
!=	

These ones do what you think.

```
       3 < 4
      4 <= 4
   6.7 > 6.3
1000 >= 1000
```

What does `3 < 4` evaluate to?
What does `type(3 < 4)` evaluate to?

We need a new data type!

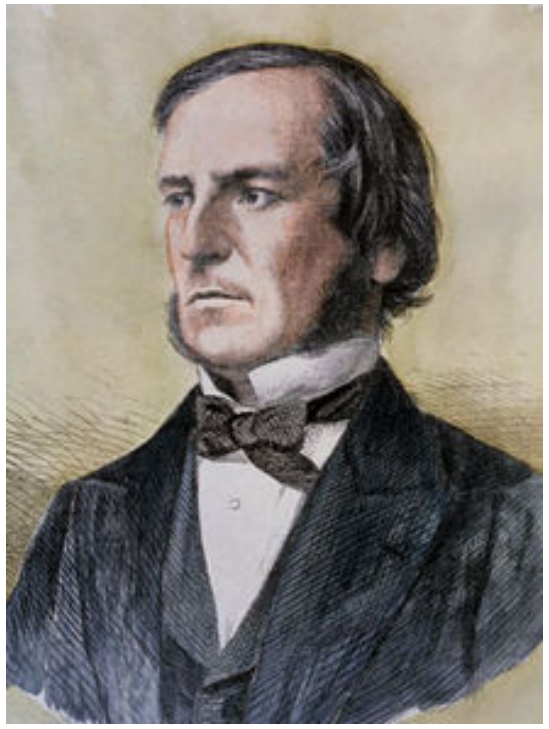
```
a < b
```

can only be one of two things:
a **true** statement or a **false** statement.

Boolean expressions are expressions that evaluate to one of two possible values: `True` or `False`

What does `3 < 4` evaluate to? `True`
What does `type(3 < 4)` evaluate to? `bool`

The `bool` data type



- Named after 19th century philosopher/ mathematician George Boole, who developed Boolean algebra
- A boolean value (`bool`) represents logical propositions that can be either **true** or **false**.
- In Python, these values are reserved keywords: `True` and `False`. Note capitalization.
- Can be used for things like `3 < 4` or `a < b`, but anything else that can be true or false:

```
is_raining = False
```

Comparison Operators

These should be familiar!

<	Less than
>	Greater than
<=	Less than or equal to
>=	Greater than or equal to
`==`	
`!=`	

Examples:

```
      3 < 4   => True
     4 <= 4   => True
  6.7 > 6.3   => True
1000 > 1000   => False
```

Comparison Operators

These should be familiar!

<	Less than
>	Greater than
<=	Less than or equal to
>=	Greater than or equal to
==	Equal to
!=	Not equal to

Examples:

```
  3 == 4    => False
  5 != 4    => True
4.0 < 4.6   => True
```

Comparison Operators

These should be familiar!

<	Less than
>	Greater than
<=	Less than or equal to
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==	Equal to
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Examples:

```
  3 == 4    => False
  5 != 4    => True
4.0 < 4.6   => True
```

Unlike some operators (e.g., //), the concept of equality has meaning for some non-numeric types:

```
  True == False   => False
 "abc" == "bcd"   => False
     "a" == "A"   => False
type(4) == type(5)   => True
       5.0 == 5   => True
```

Logical Operators

`<`	Less than
`>`	Greater than
`<=`	Less than or equal to
`>=`	Greater than or equal to
`==`	Equal to
`!=`	Not equal to
`and`	logical conjunction, logical and
`or`	logical disjunction, logical or
`not`	logical negation, logical not

`a and b` is true only when **both** `a` and `b` evaluate to `True`

`a or b` is true when **at least one** of `a` and `b` evaluates to `True`

`not` switches the value:

```
not True => False
not False => True
```

Binary vs Unary Operators

- We have already seen some binary operators and one unary operator.

- Binary operators take two operands:

```
 a + b
c // d
12 != 4
```

etc.

- Unary operators take one operand:

```
-b
not False
```

Notice: minus (-) and plus (+) can behave as unary **or** binary operators!

Truth Tables for `and`, `or`

`x and y`

		y	
		T	F
x	T	**T**	**F**
	F	**F**	**F**

If `x` is true and `y` is false, `x` and `y` is false.

If `x` is true and `y` is true, `x and y` is true.

Truth Tables for `and`, `or`

`x` **`and`** `y`

		y T	**y** F
x	T	**T**	**F**
x	F	**F**	**F**

`x` **`or`** `y`

		y T	**y** F
x	T	**T**	**T**
x	F	**T**	**F**

Operator Precedence

order of precedence

Parentheses

Exponentiation (right-to-left)

Multiplication and Division

Addition and Subtraction

order of evaluation

All are evaluated left to right except for exponentiation.

Operator Precedence: Updated

order of precedence

Parentheses

Exponentiation (right-to-left)

Unary + and –

Multiplication and Division

Addition and Subtraction

Numerical comparisons `<, >, <=, >=, ==, !=`

`not`

`and`

`or`

order of evaluation

All are evaluated left to right except for exponentiation.

Operator Precedence: Updated

order of precedence

Parentheses

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Addition and Subtraction

Numerical comparisons `<, >, <=, >=, ==, !=`

`not`

`and`

`or`

Special case:

2**-1 = 0.5

Unspecial but surprising case:

-2**2 = -4

order of evaluation

All are evaluated left to right except for exponentiation.

You can look up all the details: https://docs.python.org/3/reference/expressions.html#operator-precedence

Examples

```
print(3 != 5 and 4 < 7)

print(3 == 5 or 4 < 7)

print(not False)

print(3 == 5 or 4 > 7)

print(not 6 < 8)
```

Bigger Example

```
1 == 6 and True or (1.2 < (5 % 3))
```

Bigger Example

```
1 == 6 and True or (1.2 < (5 % 3))

1 == 6 and True or (1.2 <    2  )

1 == 6 and True or      True


False  and True or      True

     False      or      True

               True
```