4b. Conditions

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INTRODUCTION

This section lays the basics for incorporating conditions into our programs. Formally, conditions are defined as functions and operators that return true or false as their output. A common example of a condition is x > y.

To get the most out of this section, you should keep in mind the classification of operators discussed <u>here</u>. This establishes that operators can be categorized according to their number of operands. Specifically, **unary operators** act on a single operand and precede it (i.e. $\langle operator \rangle x$), whereas **binary operators** take two operands and are placed between them (i.e. $x \langle operator \rangle y$).

CONDITIONS

Conditions are represented as values with type Bool, evaluating to either true or false. These values are internally represented as integers restricted to 1 and 0.

The representation of Boolean values in the REPL varies depending on their dimension: scalar Bool values are displayed as true and false, while Bool vectors use 1 and 0. This is illustrated below.

```
x = 2
#'y' provides 'true' or 'false' as its output
y = (x > 0)
julia> y
true
```

Warning!

Parentheses are optional when writing single conditions, allowing us to write y = x > 0 rather than y = (x > 0). Nonetheless, the former

syntax is somewhat ambiguous, with the risk of being potentially misinterpreted as (y = x) > 0. To avoid confusion, it's a good practice to always include parentheses. This is especially true when working with multiple conditions, where outcomes can be drastically altered.

The condition in the previous example was defined via the operator \triangleright . More generally, conditions accept **comparison operators**, which are *binary operators* that compare values of various types (e.g., numbers and strings). The next list defines the most common ones.

Comparison Operator Meaning

x == y	equal
$x \neq y$ or $x \neq y$	not equal
x < y	lower than
$x \le y$ or $x \le y$	lower or equal than
x > y	greater than
$x \ge y$ or $x >= y$	greater or equal than

Remark

The non-standard characters appearing in the table can be written using tab completion:

- ≠ via \ne , which stands for "not equal",
- \geq via \backslash ge, which stands for "greater or equal",
- \leq via \setminus le, which stands for "lower or equal".

Remark

Comparison operators are also available as functions. For instance, the following expressions are all valid:

```
==(1,2)  # same as 1 == 2

\neq(1,2)  # same as 1 \neq 2

\geq(1,2)  # same as 1 \geq 2

>=(1,2)  # same as 1 \geq 2

>(1,2)  # same as 1 > 2
```

LOGICAL OPERATORS

Logical operators allow us to combine multiple conditions into a single one. Formally, they take Bool expressions as their operands, and return another Bool as their output. The following are the main logical operators used in Julia.

Logical Operator Meaning

x && y
x and y

x || y
x or y

!x
negation of x

Notice that & and | | | follow the syntax rules of *binary* operators.

```
x = 2
y = 3

# are both variables positive?
z1 = (x > 0) && (y > 0)

# is either 'x' or 'y' (or both) positive?
z2 = (x > 0) || (y > 0)

julia> z1
true
julia> z2
true
```

Another operator taking conditions as their operands is the "not" operator, represented by !. This is a unary operator that inverts a condition's value, changing true to false and vice versa. To use it, you simply place ! at the start of the condition (i.e., before the parentheses).

As an illustration, the variables $\boxed{\mathtt{y1}}$ and $\boxed{\mathtt{y2}}$ below become equivalent via $\boxed{!}$.

```
x = 2
# is 'x' positive?
y1 = (x > 0)
# is 'x' not less than zero nor equal to zero? (equivalent)
y2 = !(x ≤ 0)

julia> y1 #identical output as 'y2'
true
```

LOGICAL OPERATORS AS SHORT-CIRCUIT OPERATORS

A key feature of <code>&&</code> and <code>[]</code> is that they're **short-circuit operators**. This means that, once an operand is evaluated, the remaining operands are evaluated only if the previous operands didn't establish the truth or falseness of the expression. Specifically:

- $(x > 0) \mid | (y > 0)$ This expression is true when *at least one condition* is satisfied. Thus, Julia begins by analyzing x > 0. If this expression is true, it immediately returns true, without evaluating any subsequent expression. Only when x > 0 is false will Julia evaluate y > 0.
- (x > 0) && (y > 0)This expression is true if *both conditions* are satisfied. Thus, Julia begins by analyzing x > 0. If this expression is false, it immediately returns false, without evaluating any subsequent expression. Only when x > 0 is true will Julia evaluate y > 0.

Since not all operands are always evaluated, it's possible to get a result even if some operands contain invalid expressions. This is shown in the next example, where we include invalid Julia code as a condition.

```
julia> (x < 0) && (this-is-not-even-legitimate-code)
false
julia> (x > 0) && (this-is-not-even-legitimate-code)
ERROR: UndefVarError: `this` not defined
```

```
julia> (x > 0) || (this-is-not-even-legitimate-code)
true
julia> (x < 0) || (this-is-not-even-legitimate-code)
ERROR: UndefVarError: `this` not defined</pre>
```

PARENTHESIS IN MULTIPLE CONDITIONS

The inclusion of parentheses isn't crucial when working with only two conditions. This is because expressions like (x > 0) && (y > 0) can be safely written as x > 0 && y > 0, without much risk of confusion.

On the contrary, when dealing with three or more conditions, the lack of parentheses can drastically impact the expected behavior of an expression. The following example illustrates this point.

```
x = 5
y = 0

julia> [x < 0 && y > 4 || y < 2]
true</pre>
```

```
x = 5

y = 0

julia> (x < 0) && (y > 4 || y < 2)

false
```

```
x = 5

y = 0

julia> (x < 0 && y > 4) || (y < 2)

true
```

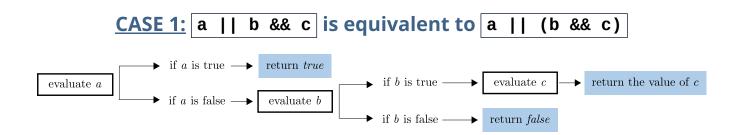
In the example, the expression without parenthesis is equivalent to the last tab's, since & has higher precedence than | | | in Julia: when both & and | | | are used, & will be evaluated first.

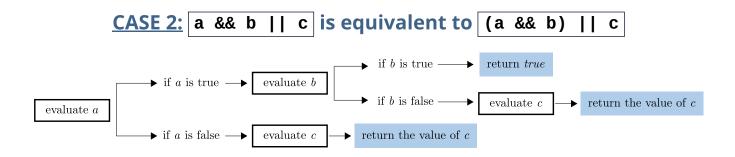
To avoid confusion when more than two conditions are incorporated, **we'll always add parentheses**. This improves readability and spares us the need to memorize specific rules. The next optional subsection covers Julia's precedence rules in more detail. However, if you'll consistently enclose conditions in parentheses, you can safely skip it.

MULTIPLE CONDITIONS WITHOUT PARENTHESES (OPTIONAL)

To simplify the explanation, let's focus on cases with three conditions. These conditions will be represented through [Bool] variables [a], [b], and [c], with each variable possibly representing expressions like [x > 0].

The following diagrams describe the process for evaluating a && b || c and a || b && c , based on these two rules.





To illustrate the rules in practice, let's go through several examples that combine true/false values for a, b, and c. In these examples, we'll use the invalid expression does-not-matter. This is to emphasize that some conditions aren't necessarily evaluated thanks to the short-circuit behavior of and | | and | | |.

```
julia> false || true && true

true
julia> false || true && false

false
julia> true || does-not-matter

true
```

```
julia> true && false || true

true

julia> true && false || false

false

julia> false && does-not-matter || true

true
```

FUNCTIONS TO CHECK CONDITIONS ON VECTORS: "ALL" AND "ANY"

Julia provides two built-in functions called all and any to evaluate multiple conditions in a collection. The function all returns true if every condition is true, whereas any returns true if at least one condition is true. The functions require either directly specifying the conditions through a Boolean vector or defining the condition to check through a function. Next, we cover each case separately.

VECTORS FOR REPRESENTING MULTIPLE CONDITIONS

In the following, we demonstrate the syntax of all and any when they take a Boolean vector as their argument.

```
a = 1
b = -1

# function indicating whether all elements satisfy the condition
are_all_positive = all([a > 0, b > 0])

# function indicating whether at least one element satisfies the condition
is_one_positive = any([a > 0, b > 0])

julia> are_all_positive
false
julia> is_one_positive
true
```

The function all returns true only when all the conditions are satisfied, thus requiring that each vector's entry is positive. This doesn't hold in the example, since b = -1. Conversely, any returns true when at least one of the conditions holds, thus requiring at least one element in the vector to be positive. This is satisfied in the example, since a = 1.

As we indicated, $\boxed{\text{all}}$ and $\boxed{\text{any}}$ do not support passing multiple conditions as separate arguments. This entails that expressions like $\boxed{\text{all}(a > 0, b > 0)}$ aren't allowed. Nevertheless, this restriction actually makes the functions more flexible, as they **enable the use of broadcasting operations for checking multiple conditions**. For example, the following code snippet implements the same operations as above, but through a vector $\boxed{\mathbf{x}}$.

```
x = [1, -1]
are_all_positive = all(x .> 0)
is_one_positive = any(x .> 0)

julia> are_all_positive
false
julia> is_one_positive
true
```

FUNCTIONS FOR REPRESENTING MULTIPLE CONDITIONS

In addition to expressing conditions through vectors, all and any allow **passing a function to represent the condition to check**. The syntax for this is all(<function>, <array>) and any(<function>, <array>), where <function> can be an anonymous function. The following examples demonstrate how to implement all(x .> 0) and any(x .> 0) using this approach.

```
x = [1, -1]
are_all_positive = all(i -> i > 0, x)
is_one_positive = any(i -> i > 0, x)

julia> are_all_positive
false
julia> is_one_positive
true
```

By passing a function as an argument, all and any can additionally be employed **to evaluate the same condition across multiple vectors**. This is achieved by broadcasting all and any.