Object types

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Prologue:

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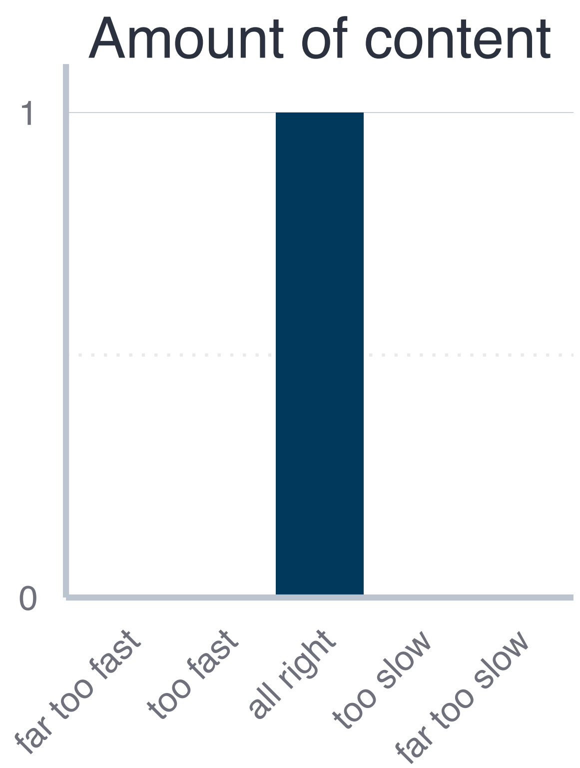
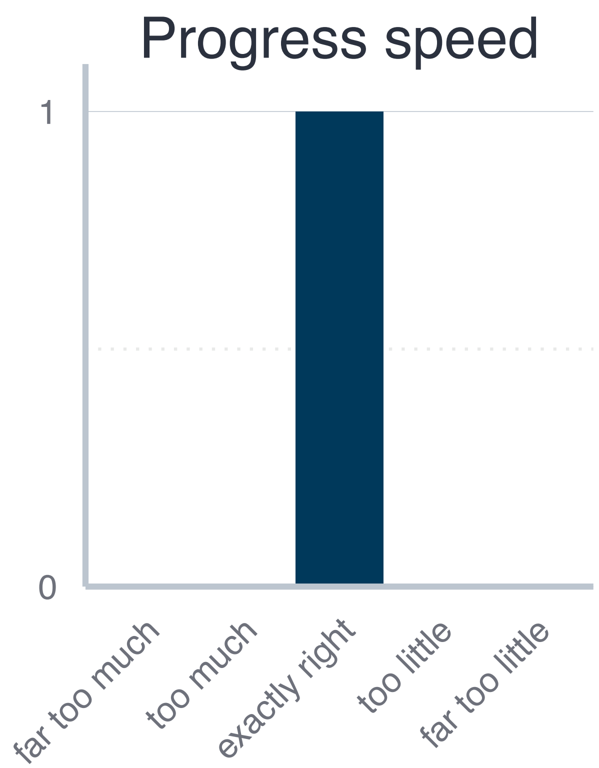
Feedback and exercises

- One of you filled out the feedback survey. Main results:





Highlights
- Learning about assignments

Lowlights
- Nothing 🥰

- What were the main problems with the **exercises**?
  - Please use the Moodle forum…and please do the exercises!

Goals for today

I. Understand the main object types in R and their practical relevance

II. Learn how to transform object types into each other

III. Hear about some useful helper functions and the concept of vectorisation

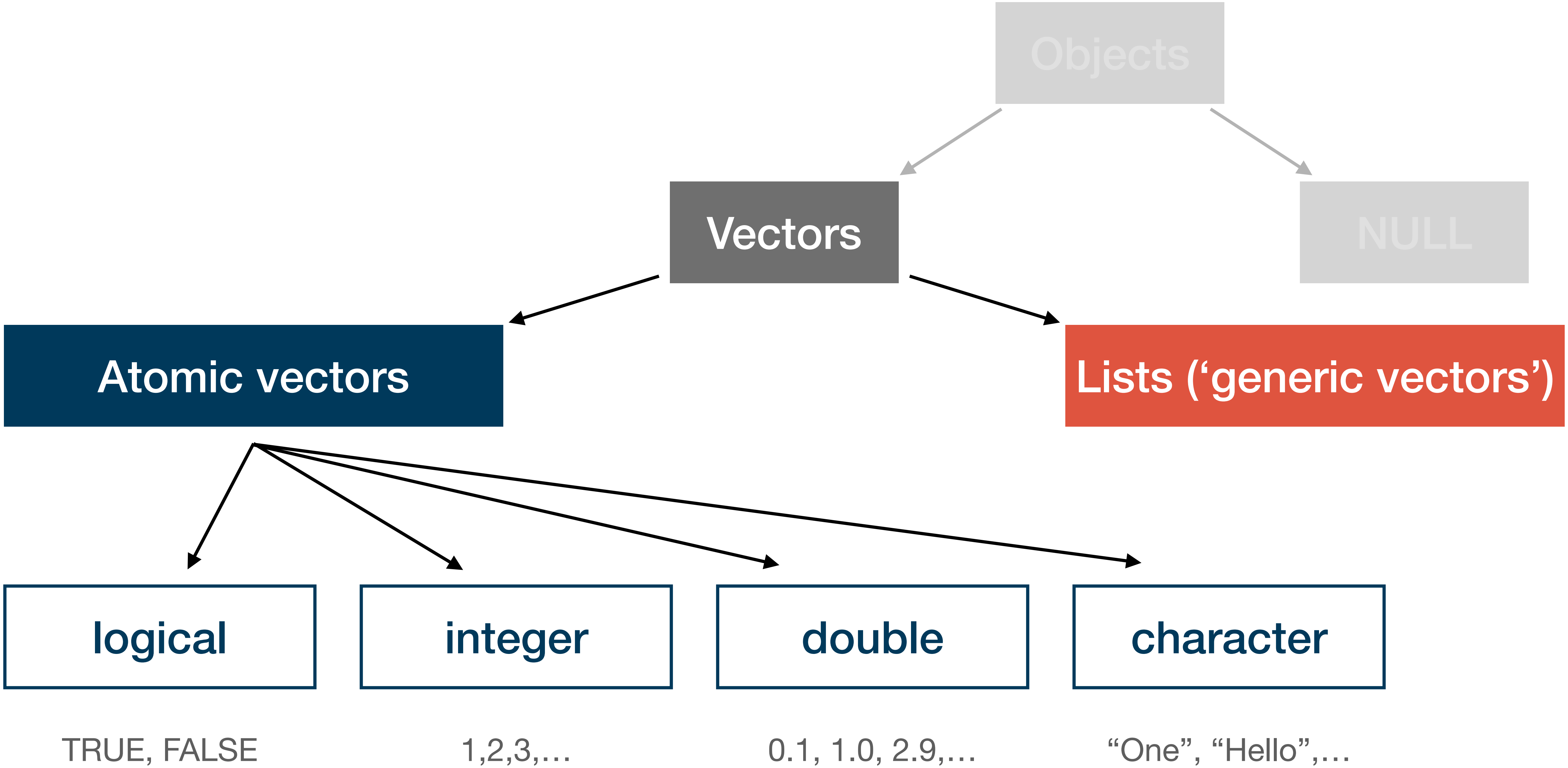
Basic object types in R

Object types in R

> “To understand computations in R, two slogans are helpful:
> Everything that exists is an **object**.
> Everything that happens is a function call.
>
> John Chambers

- We have learned quite a bit about functions, now we turn to objects
- We must distinguish different object types because functions operate differently depending on the type of the object we are processing
  - E.g.: ‘adding up’ numbers is different than ‘adding up’ words
- Fortunately, there are only a few basic types you must know about
  - More complex types are natural modifications of these basic types
- The most general type of object in R is a **vector**

Basic object types in R



- Among the more specific vector types, we will learn about `factors` and `data frames` later

Atomic vectors

- Atomic vectors are composed only of objects of the same type
  - We say that an atomic vector is of the same type as are its elements
  - We can test for this type using the function `typeof()`
- There are four main types of atomic vector that are most important:

Logical values: logical

- Only two* options: `TRUE` or `FALSE`
- Often the result of logical operations (e.g. `4>2`)

Whole numbers: integer

- A whole number, followed by L:
- `1L, 2L, 100L`, etc.
- Often the result of counting

Decimal numbers: double

- A number with the decimal sign `.`
- `2.0, 0.8, -7.5`, etc.
- The ‘standard’ number you will use

Letters and words: character

- Might contain all kinds of tokens and start and end with `"`
- `"2", "Hello!", “vec_1"`, etc.

*: We will see later that missing values are also considered logical in some instances, but this is basically irrelevant now.

Creating atomic vectors

- The easiest way to create atomic vectors is the function `c()` ('concatenate')

```
t_vec <- c(1, 2, 3)
```

- The number of elements that are part of a vector are its length:
  - You can test for the length of a vector using `length()`:

```
length(t_vec)
```

- `c()` can also be used to merge atomic vectors or arbitrary length:

```
t_vec_2 <- c(4, 5, 6)

t_vec_full <- c(t_vec, t_vec_2)
```

Coercion

- Sometimes we might want to change the type of an atomic vector
- In this context, the functions `as.*()` and `is.*()` are useful
  - Substitute the `*` for the type of vector, and you can test and transform them:

```
xx <- “2”

is.double(xx)

yy <- as.double(xx)

is.double(yy)
```

- But be beware of some counter-intuitive transformation behaviour:
  - `as.integer(22.9)`
  - `as.logical(99)`

Intermediate exercises

Do the following tasks with you neighbour(s) and discuss open questions!

1. Create a vector containing the numbers 2, 5, 2.4 and 11.

2. What is the type of this vector?

3. Transform this vector into the type `integer`. What happens?

4. Do you think you can create a vector containing the following elements: `"2"`, `"Hallo"`, `4.0`, and `TRUE`? Why? Why not?

Some useful helper functions

- There are some types of atomic vectors that you create frequently
  - Sequences of numbers, concatenated words, or repetitions
- For case 1 you may use the function `seq()` with the following arguments:
  - `from, to`: starting and end values of the sequence
  - `by`: increment steps of the sequences (must be numeric)
  - `length.out`: desired length of final sequence
  - `along.with`: creates sequence of same length as object
- Only one of the arguments (ii), (iii), and (iv) can be used, e.g.:
  - `seq(-5, 5, by=2.5) ; seq(1, 4, length.out=10)`

Some useful helper functions

- There are some types of atomic vectors that you create frequently
  - Sequences of numbers, concatenated words, or repetitions
- For case 2 you may use the function `paste()` with the argument `sep`:
  - `sep:` How should the input vectors be separated?
- This is useful, for instance, if you want to create file names:

```
paste("file_", seq(1,4), ".pdf", sep = “")
```

- Finally, if you want to repeat something, use `rep()`:

```
rep("Cool!", 5)
```

Indexing

- Indexing means referencing a particular position of a vector
  - You do this by adding the position in square brackets to the end of the vector
  - `v_c[3]`, for instance, returns the third element of the vector `v_c`
  - You can also use this logic to replace these elements:

```
v_c <- c("First", "Second", "Second", "Fourth")
v_c[3] <- "Third!"
```

- But you cannot use this to add new elements to a vector:

```
v_c[5] <- "Fifth…"
```

- Add a fifth element to the vector `v_c`!

Vectorisation

- One reason why atomic vectors are so popular is that they allow for very fast computations
  - For the computer it is much easier to work with sets of objects that all behave the same
- **Vectorisation** means that an operation is applied to each element of a vector:

```
v_2 <- seq(1, 5)

v_2**2
```

- "**To vectorise**" a task means to write it in a way that operations are applied to atomic vectors → in R, you should do that whenever possible
  - A slower alternative are **loops**, which we learn about later and which are unavoidable in certain situations

Intermediate practice

Do the following tasks with you neighbour(s) and discuss open questions!

I. Create a vector with the numbers from `-2` to `19` (step size: `0.75`)

II. Create an index vector for this first vector (note: an index vector is a vector with all possible indices of the original vector)

III. Compute the log of each element of the first vector using vectorisation. Anything that draws your attention?

IV. What happens if you concatenate vectors of different types using `c()`? Can you derive a systematization?

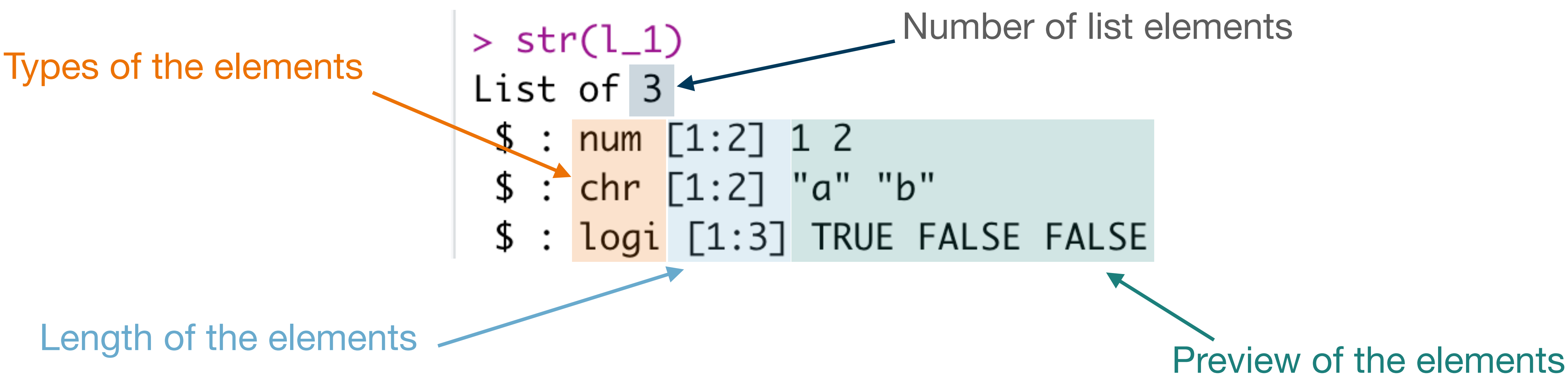
- Remember that you can check for the type of an atomic vector using `typeof()`

Lists

- The second major type of vectors → sometimes called generic vectors
- Difference to atomic vectors: lists may contain objects of different types
  - Thus, the type of a list is always…

```
l_1 <- list(c(1,2), c("a", "b"), c(TRUE, FALSE, FALSE)); typeof(l_1)
```

- Lists can be complex → get an overview using `str()`:



Naming and indexing of lists

- The different elements of lists can be named:

```
l_2 <- list("numbers"=c(1,2),
            “letters"=c("a", "b"),
            "logics"=c(TRUE, FALSE, FALSE))
```

- You can retrieve the names using `names()`:

```
names(l_2)
```

- You can subset the list using the names:

```
l_2["letters"]
```

- And access the elements of the sublists with `[[`:

```
l_2[["letters"]]
```

  - Alternatively use the shortcut `$`: `l_2$letters`

Practical differences to atomic vectors

- There are two very important differences to atomic vectors:
  - Vectorisation does not work for lists
  - Indexing works differently for lists
- To illustrate the first issue compare:

```
v_ <- c(1, 2, 3); 2*v_
l_ <- list(1, 2, 3); 2*l_
```

- To illustrate the latter:

```
typeof(l_[1])
typeof(l_[[1]])
```

- Lists are fundamental to more complex data structures we will encounter later

Final remarks on basic object types

- There are two "strange" data types: `NA` and `NULL`
- `NA` is used to represent absent elements of vectors
  - Happens frequently when vectors contain observations
  - Many functions behave differently when NAs are present (remember `na.rm`!):

    ```
    mean(c(1,2,NA)) ; mean(c(1,2,NA), na.rm = TRUE)
    ```
- You test for `NA` using `is.na()`:

  ```
  is.na(c(1, 2, NA))
  ```
- To check whether a vector contains missing values, use `anyNA()`:

  ```
  anyNA(c(1,2,NA))
  ```

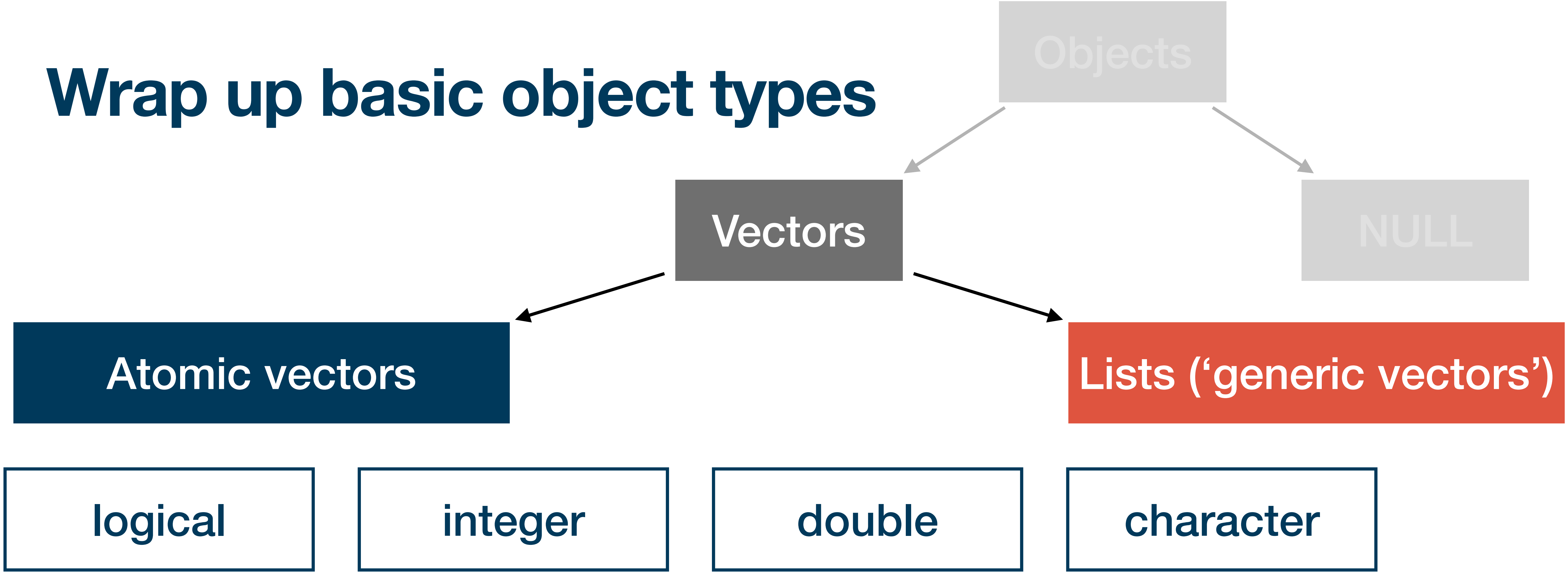
Final remarks on basic object types

- There are two “strange” data types: `NA` and `NULL`
- `NULL` is in fact a data type in itself, but in practice its best thought of as a vector of length zero:

```
c()
typeof(NULL)
length(NULL)
is.null(NULL)
```

- You might use `NULL` mainly in two instances:
  - Represent an empty vector of arbitrary type
  - Represent and absent vector (≠ `NA`, which represents absent elements of vectors)

Wrap up basic object types



- The central take-aways concern:
  - How to test for and transform these types: `typeof()`, `is.*()`, `as.*()`
  - How to index them: `[`, `[[`, `$`
  - How to create typical instances: `rep()`, `paste()`, `seq()`
- We learned about vectorisation and its attractiveness in R
- We also encountered “strange” types such as `NA`, `NULL` and `NaN`

Summary and outlook

- Next week we will learn about two more advanced object types: `factor`s and `data.frame`s
- We will learn how our knowledge about the basic object types helps us to deal with more advanced types, and how they relate to each other

Tasks until next week:

1. Fill in the **quick feedback survey** on Moodle
2. Read the **tutorials** posted on the course page
3. Do the **exercises** provided on the course page and **discuss problems** and difficulties via the Moodle forum