

Foundations of Data Science for Biologists

R: data import, data frames, and data types

BIO 724D

03-SEP-2024

Paul Magwene and Greg Wray

Data types and data structures

Data types

Computers work with 0s and 1s — but you want to work with numbers, names, dates, etc.

Data types instruct programs how to interpret and process different kinds of data

Common data types in R are numeric, integer, character, and logical

R has an extensive set of rules for each data type:

What **values** are allowed (e.g., an integer can be 42 but not '42' or 42.7)

What **operations** are allowed (e.g., division for integers but not character or logical)

How to **display** data in human-readable form (e.g., 01010010 as R or 82)

Variables point to data

When you create a variable in R, two things happen

R stores two kinds of information in a single package:

Data: values, such as `-23.84` or `'Adelie'` or a sequence of values

Metadata: what kind of information is being stored, how many values, etc.

The package is called an **object**

R stores the variable name and the memory address of the object in a separate table

That table contains the names and address of all the variables currently in use

Now, when you type the variable name, R knows:

Where the data are stored and how many values there are

How to interpret the data: as numbers, letters, true/false, etc.

What a data frame looks like to you

penguins



species	island	bill_length_mm	sex
Adelie	Torgersen	39.1	male
Adelie	Torgersen	39.5	female
Adelie	Biscoe	37.8	female
Adelie	Biscoe	37.7	male

What a data frame looks like to R and your computer

penguins

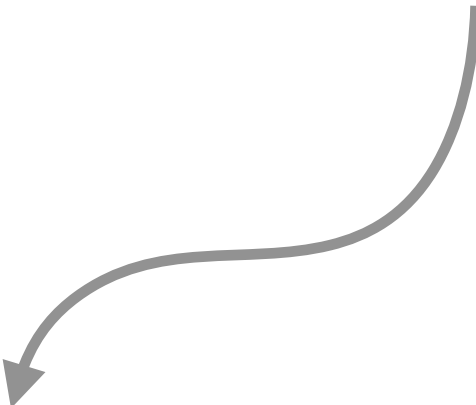


0x136dd5608

00000000
01111000
00110001
00110011
00110110
01100100
01100100
00110101
00110110
00000000
00111000



type		length	data				names			
							species	island	bill_length_mm	sex
list		4	0x120a6d600	0x120c37400	0x120c2ba00	0x136aa9a00				
0010111	00000100	00000000	etc.	etc.	etc.		01110011	01101001	etc.	etc.
		01111000					01110000	01110011		
		00110001					01100101	01101100		
		00110010					01100011	01101100		
		etc.					01101001	01101110		
							01100101	01100100		
							01110011			



type	length	data			
char	4	Adelie	Adelie	Adelie	Adelie
01100011	00000100	01000001	01000001	01000001	01000001
		01100100	01100100	01100100	01100100
		01100101	01100101	01100101	01100101
		01101100	01101100	01101100	01101100
		01101001	01101001	01101001	01101001
		01100101	01100101	01100101	01100101

Data structures

A data frame is an example of a **data structure**

- Data structures are built from more basic data types

- Defines what kinds of data can be stored (can be multiple types and dimensions)

- Defines what operations are permitted

- Usually optimized to work very efficiently with data in specific ways

For example, a data frame:

- Allows for arbitrary number of columns of mixed data types

- Requires all columns to be of the same length

- Allows for labels to be attached to columns (a type of metadata)

Taxonomy of basic data structures in R

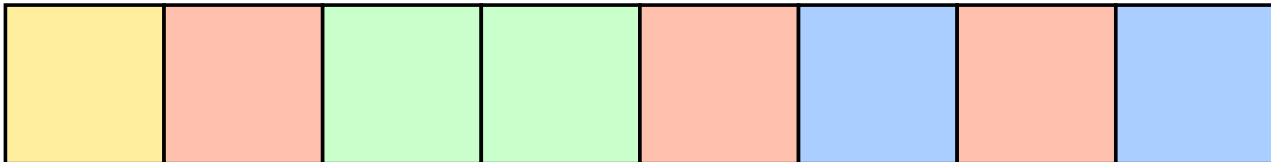
homogenous

mixed

1-dimensional

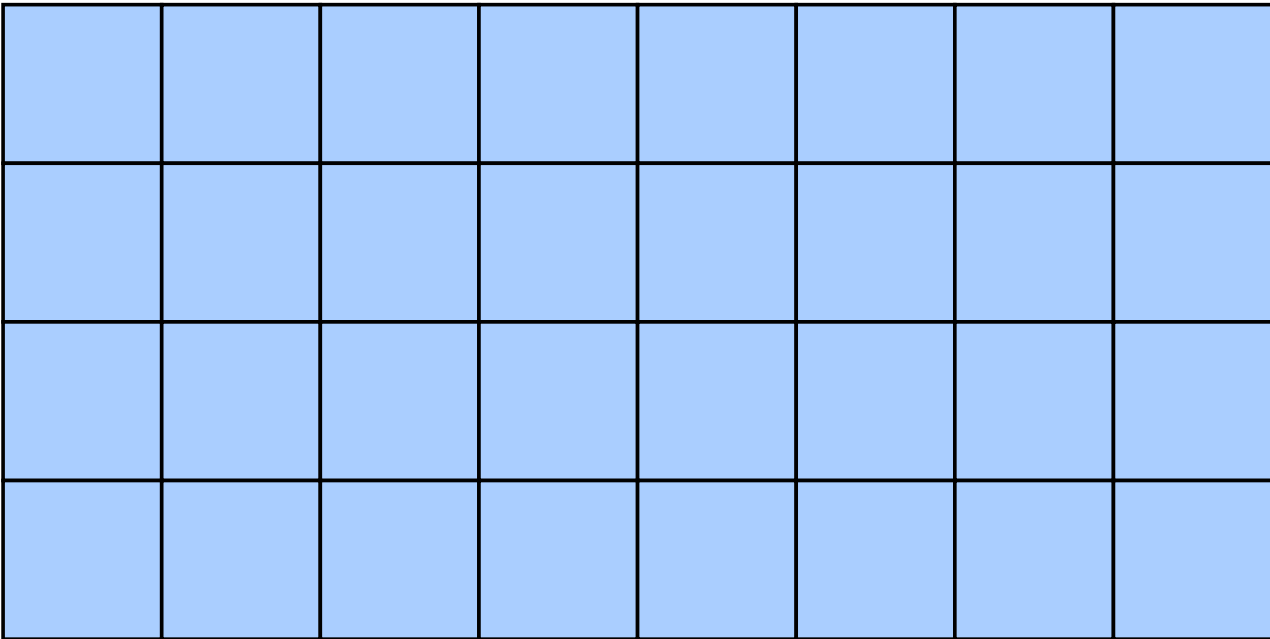


vector

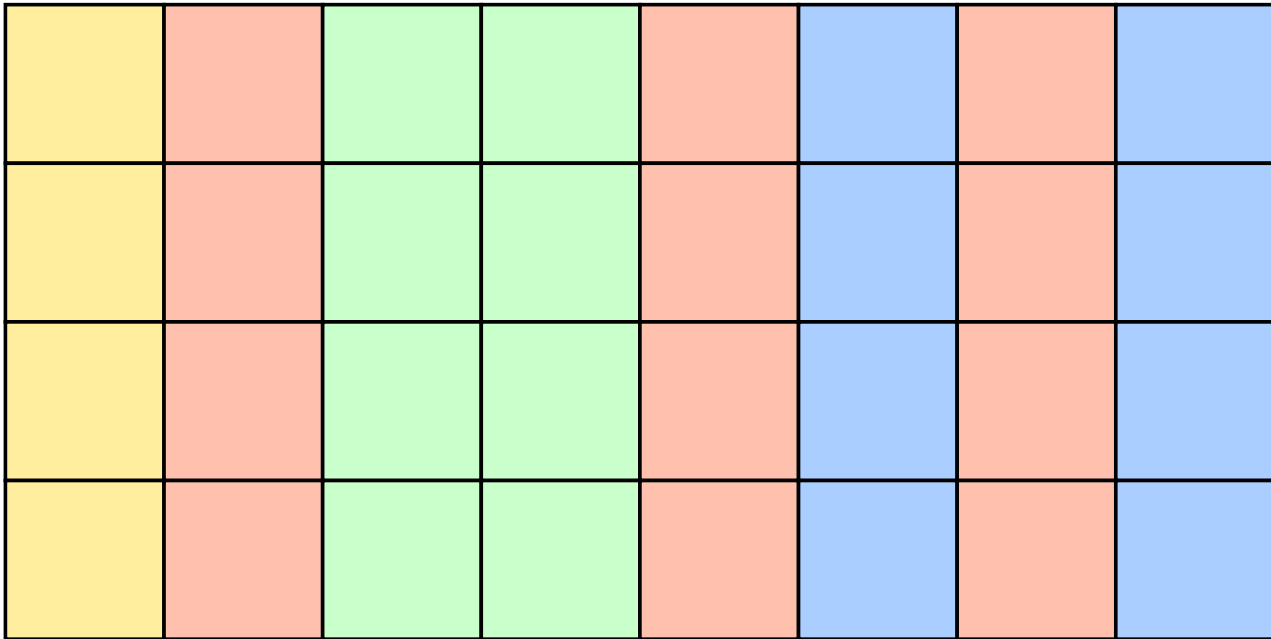


list

2-dimensional



matrix



data frame

Vectors are the most basic data types in R

Vectors are also called **atomic** data types for this reason

Four atomic data types are very commonly used:

Numeric: real numbers; double-precision floating point by default

Integer: whole numbers

Logical: **TRUE**, **FALSE** (called **Boolean** in some languages)

Character: strings composed of letters, numerals, symbols, and whitespace

Two additional atomic data types are available but are rarely needed:

Complex: imaginary numbers with values like **2+3i**, where $i^2 = -1$

Raw: bytes with no implied meaning

What is a tibble?

tidyverse encourages using tibbles in place of data frames as the tabular data structure

A **tibble** is a data frame with slightly different behavior

Be aware, as you may encounter data as tibbles

To convert a tibble into a standard R data frame:

```
my_dataframe <- as.dataframe(data_in_tibble)
```

Check the tibble documentation for details: <https://tibble.tidyverse.org/>



Working with data structures in R

Naming data objects

R has some simple rules for naming data objects:

- Must start with a letter *or* . (dot) immediately followed by a letter

- May include: letters, numbers, underscore, dot, standard keyboard symbols

- May not include spaces (there is a work-around, but spaces are usually a bad idea)

- Case-sensitive

- Can be arbitrarily long

- Cannot be a **reserved word**; type `help(reserved)` or `?reserved`

Best practices

- When writing programs, favor descriptive, long names over simple, short ones

- Avoid relying on case and using symbols (other than underscore and dot)

- Avoid naming variables with the names of functions (although this is allowed!)

Use assignment method to create any kind of data object

The basic form of assignment is:

```
my_obj <- 7
```

read as: “my_object gets 7”

```
my_obj <- c(7, 14, 21)
```

creates an integer vector of length 3

Other valid forms of assignment:

```
7 -> my_obj
```

sometimes more readable

```
my_obj <- 7 -> other_obj
```

assigns value 7 to two different variables

```
A <- B <- C <- 7
```

assigns value 7 to three different variables

```
my_obj = 7
```

alternative assignment (not recommended)

```
assign(my_obj, 7)
```

using a function (but awkward!)

Use a **shortcut** for the assignment operator: alt+minus (Win) / opt+minus (Mac)

Data objects

The process of assignment creates a package of information called a **data object**

The identifier and associated value(s) are stored together in memory

Metadata are also stored: always data type and length; often additional information

You can learn about a data object in several ways, including:

<code>my_var</code>	returns current value(s)
<code>typeof(my_var)</code>	returns the object's specific data type
<code>class(my_var)</code>	returns the object's more general data type or structure
<code>length(my_var)</code>	returns the number of items in the data object
<code>str(my_var)</code>	returns a description of the structure of a data object
<code>attributes(my_var)</code>	returns the non-standard metadata of a data object
<code>View(my_var)</code>	displays all the data in a scrollable window (RStudio only)

Converting between data types

It is often possible and useful to convert between data types (called **coercion** in R)

Must be a homogenous data type (vector, matrix, or column in a data frame)

Must make logical sense (e.g., “2” can be coerced to integer but “kangaroo” cannot)

To coerce, use `as.integer()`, `as.logical()`, `as.character()`, etc.

Coercion rules to be aware of:

Numeric to integer	truncates any decimal values (does not round!)
Numeric to logical	<code>0</code> becomes <code>FALSE</code> ; non-zero values become <code>TRUE</code>
Logical to numeric	<code>TRUE</code> becomes <code>1</code> , <code>FALSE</code> becomes <code>0</code>
Numeric to character	numerals and symbols become characters
Character to numeric	must be a formatted number (<code>-</code> , <code>+</code> and <code>.</code> allowed)

And many more; check documentation to avoid unexpected results!

Missing values

R provides three special values that represent missing, invalid, or undefined information

NA a missing value; acronym = not available

NaN an invalid mathematical result (e.g., $0/0$); acronym = not a number

NULL a value that is undefined (e.g. vector of length 0)

Points to remember:

Do not use quotes: `'NA'` is interpreted a character value

Do not use in mathematical operations: `my_var + NA` substitutes every item with `NA`

Do not use in logical tests: `my_var == NA` returns `NA`

To identify missing values:

`is.na(my_vec)` returns a logical vector with NAs FALSE, all others TRUE

`which(is.na(my_vec))` returns the position(s) of any NAs in the vector

Assignment has many uses

Store the result of an operation:

```
my_var <- 1 + 2
```

evaluates RHS and assigns result to LHS

```
my_vec <- old_vec * 3
```

multiplies each element by 3 during assignment

Create a new data object:

```
my_vec <- c(1:10)
```

creates a numeric vector containing values 1-10

```
my_list <- list(1, "a")
```

creates a list containing values 1 and "a"

Update 1 or more values in an existing data object:

```
my_vec[10] <- 42
```

changes the value of item 10 to 42

```
mvec[1:length(mvec)] <- 42
```

replaces every value with 42, preserving length

```
my_vec <- 42
```

re-binds my_vec to a single value, length = 1

```
my_vec[is.na(my_vec)] <- 0
```

replaces NAs with 0; other values unchanged

Assignment has many uses, *continued*

Add items to an existing data object:

`my_vec[11] <- 300` adds 1 item to a vector containing 10 items

`my_vec[12:15] <- c(1,3,4)` adds 3 items to a vector containing 11 items

Delete items from an existing data object:

`my_vec <- my_vec[c(1,3,6)]` removes all items except 1, 3, and 6

`my_vec <- my_vec[1:3]` removes all items except the first 3

Copies an existing vector:

`new_vec <- old_vec` copies values from one vector to another

Create a logical vector to use for subsetting or counting:

`logic_vec <- age_vec < 3` assigns TRUE and FALSE values accordingly

`logic_vec <- is.na(my_vec)` assigns TRUE and FALSE values accordingly

