R Lesson 2: Objects and Data Structures

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Preliminaries

Common types of data

- **character**, e.g. "Fred" or "!@#ts23" (in quotes)
- **numeric**, e.g. 15 or 6.02 (no quotes)
- **logical**, TRUE or FALSE (all caps, no quotes)

Object name recommendations

- Be descriptive (what the object is or does)
- **snake_case** (underscores) is commonly used:
  - `ordinary_relational_processes`
- camelCase is sometimes used:
  - `bookList`, `alphabetizeParticipants`
- We can use the term **variable** to refer to named objects
- R doesn't know what a name "means". A meaningful name helps human readers of the code.

Assigning a value to an object

- You can **assign** a value to an object using **<-** (similar to a left arrow)
- Examples:

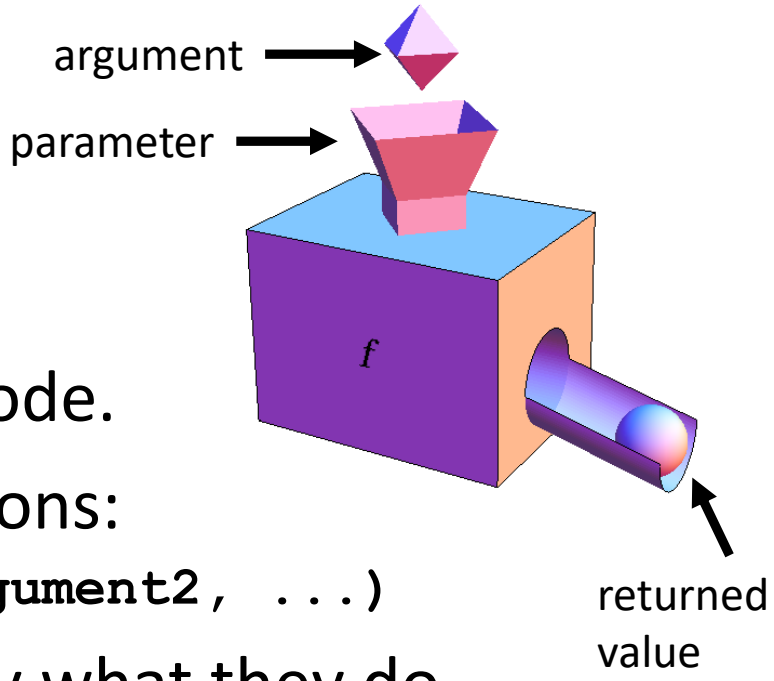
  `name <- "Steve"` (creating a character object)

  `my_number <- 6.02` (creating a numeric object)
- Using the equals sign (=) is allowed, but not recommended.
- alt-minus is an RStudio shortcut to generate **<-**

"Printing" the value of an object

- R does not have a "print" command.
- entering the name of an object (or expression) in the console evaluates and displays its value

Functions



- A **function** defines a block of code.
- We pass **arguments** into functions:

```
function_name(argument1, argument2, ...)
```

- Functions are usually named by what they do. Example:

```
my_latte <- make_latte(beans, milk, water)
```

- Functions can be:
  - built-in to R
  - defined by you in your code
  - defined by somebody else in a package

Using a function

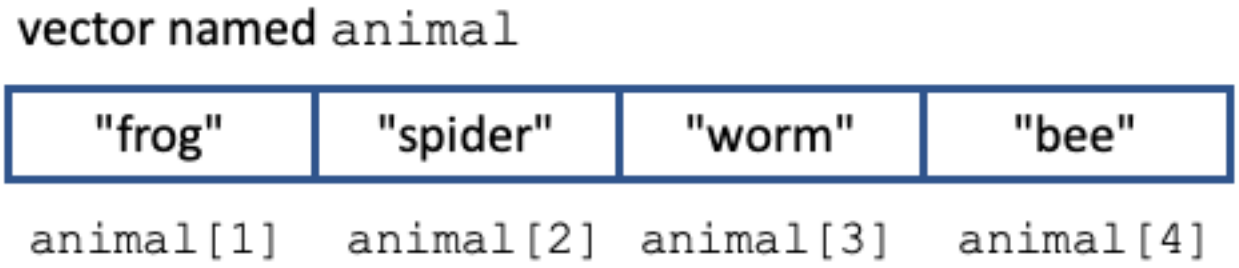
- We don't have to know anything about the code that makes a function work. We just need to know:
  - What the function does
  - What arguments to put into it
  - What the function will output
- Examples:

  `sqrt(2)` (evaluate and display)

  `x <- sqrt(3)` (evaluate and assign to an object)

Vectors

Vectors are king in R



- A **vector** is the most common kind of data structure in R.
- Vectors contain a sequence of the **same type** of data.

Creating vectors

- We commonly use the **construct** function to make vectors:

```
number_vector <- c(1, 3, 6, 10, 15)
animal <- c("frog", "spider", "worm", "bee")
```

- We can also generate a **sequence** of numbers:

```
number_range <- 3:9
count_down <- 10:0
go_negative <- 5:-3
```

- The generated sequence is just another vector!
- (Python users: note the range includes the final value)

Knowing what's going on with a vector

- display it in console
- examine its value in the environment data pane
- examine its properties:

  `length(animal)` (how many items)

  `mode(animal)` (type of data in vector)

Referencing parts of vectors

- Referencing a **single item**:

  `animal[3]` (displays the third item)

  `animal[2] <- "arachnid"` (assigns "arachnid" to the 2nd item)

- Referencing a **range of items** (subvector):

  `animal[2:4]` (the range 2:4 is actually a vector itself)

- (Python users: R vectors are "1 based"; the first item is numbered 1, not 0. Also, the range includes the final value.)

Single item objects are vectors, too.

- Surprisingly, a single data item assigned to an object is also a vector. We can see this if we ask its length as if it were a vector:

```
an_item <- "some character string"
length(an_item)
```

- We can reference the single item using vector notation:

```
an_item[1]
```

Operations on vectors

- Many functions work equally well for a single item or a multi-item vector (since they are both vectors):

```
number_vector <- c(1, 3, 6, 10, 15)
sqrt(number_vector)
```

- When operations are performed on vectors, they generally are performed on **all items** in the vectors.

```
> a <- c(10, 30, 100)
> b <- c(5, 10, 20)
> c <- a/b
> c
[1] 2 3 5
```

More complicated things are also vectors

- A **matrix** is a vector that has been assigned two dimensions
- An **array** is a vector that has been assigned any number of dimensions
- As forms of vectors, matrices and arrays can only consist of one kind of data.
- Example:

```
a_vector <- c(1.1, 1.2, 2.1, 2.2, 3.1, 3.2)
a_matrix <- matrix(a_vector, 2, 3)
```

Missing data indicators

- R's built-in indicators for **missing data**:

  NA ("not available") means there is a value, but it's missing; length =1

  NULL means no value; length=0

```
vector_with_missing <- c(1, 2, NA, 3)
```

- NA will prevent some calculations. Example:

```
mean(vector_with_missing)
```

- NA can be used for missing data in tables instead of blank cells

Other important data structures

Lists

list named `thing`

name	*fruitKind*	*euler*	*vectorData*	*curse*
value	"apple"	2.71828	animal	"!@#$%"
reference value by position	`thing[[1]]`	`thing[[2]]`	`thing[[3]]`	`thing[[4]]`
reference value by name	`thing$fruitKind`	`thing$euler`	`thing$vectorData`	`thing$curse`

- Like vectors, **lists** are one-dimensional data structures.
- However, lists can be **heterogeneous** (contain more than one kind of data object)
- It is typical to give names to values of a list.

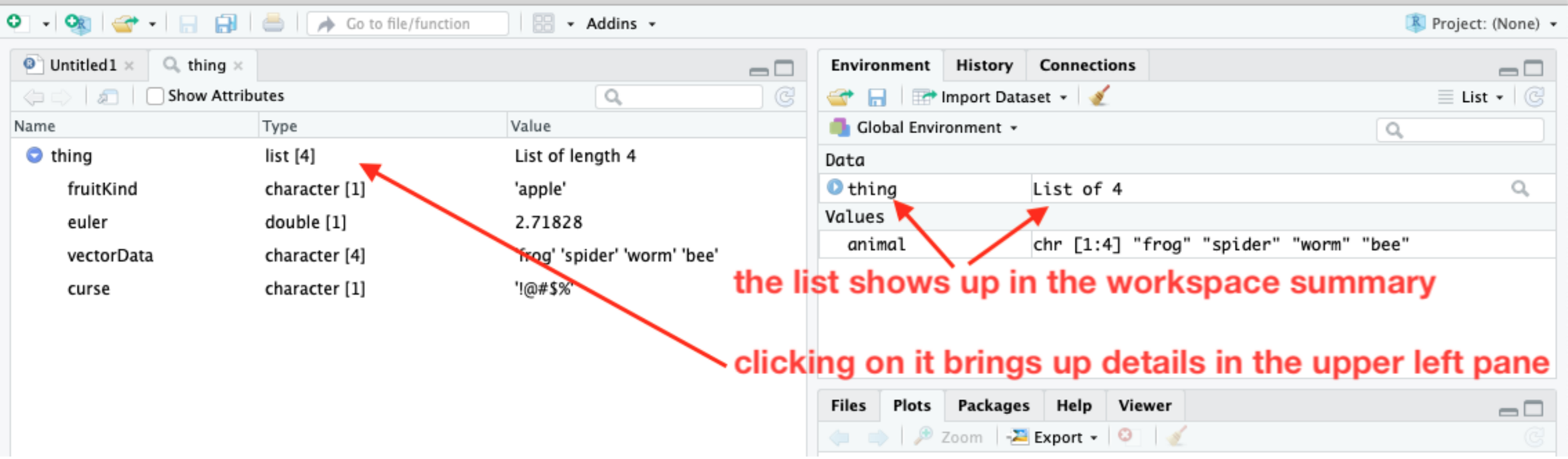
Creating a list

- Lists are created using the **`list()`** function:

```
thing <- list(fruit_kind="apple",
              euler=2.71828,
              vector_data=animal,
              curse="!@#$%")
```

- This list contains character strings, a number, and a vector.
- Values can be assigned names as they are added to the list

Viewing contents of a list



- You can see what's in a list by clicking on its name in the workspace summary in the Environment pane

Referencing list items

- List items can be referenced by:
  - **position** using double square brackets and the index number

    ```
    thing[[2]]
    ```

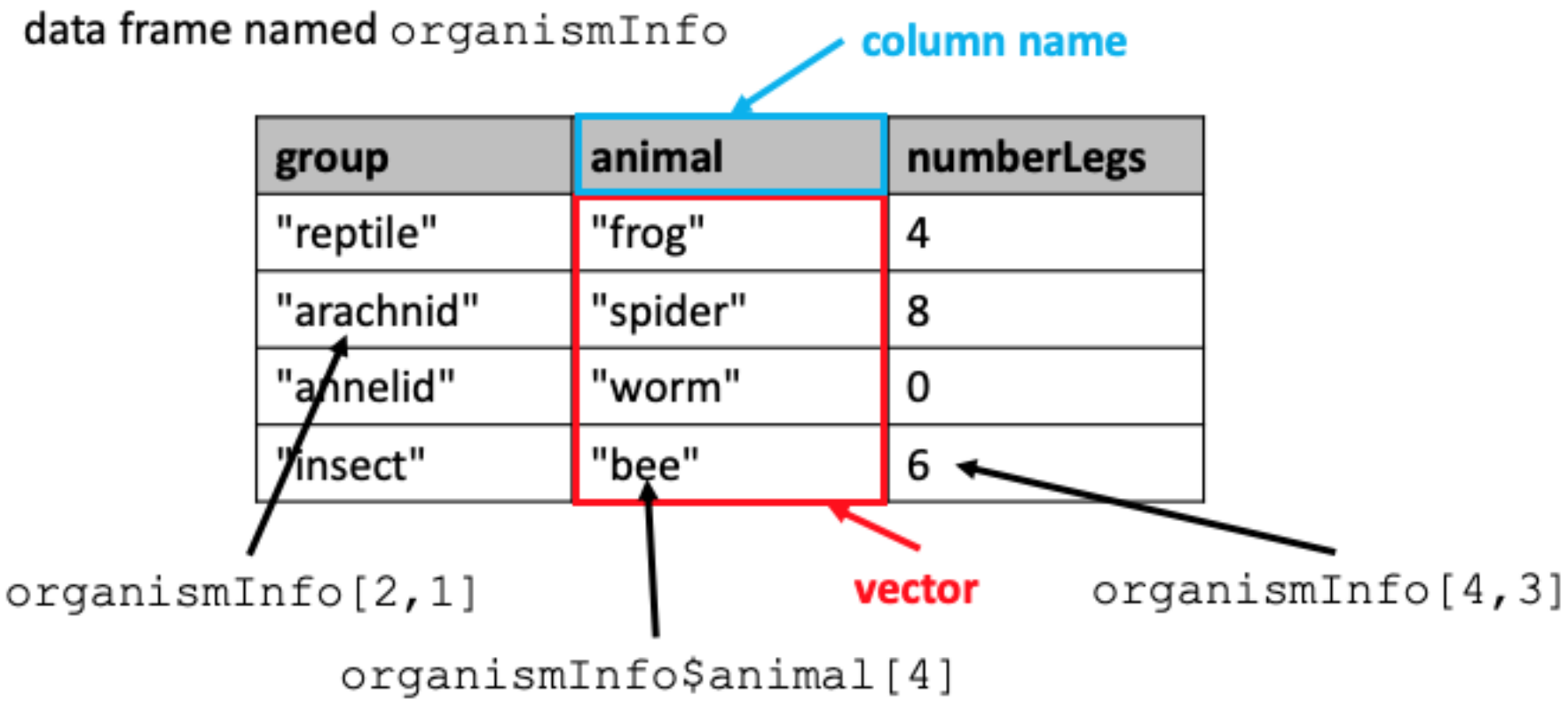
  - **name** using a dollar sign and the name string

    ```
    thing$curse
    ```

Clearing the contents of a pane

- Click on the little broom near the top of the pane
- The view in the pane will be cleared
- In the case of the Environment pane, the values will also be cleared.

Data frames



- **Data frames** are essentially tables
- The **column values** are like **vectors**
- The **set of columns** is like a **list**

Making a data frame from vectors

- First make the named vectors

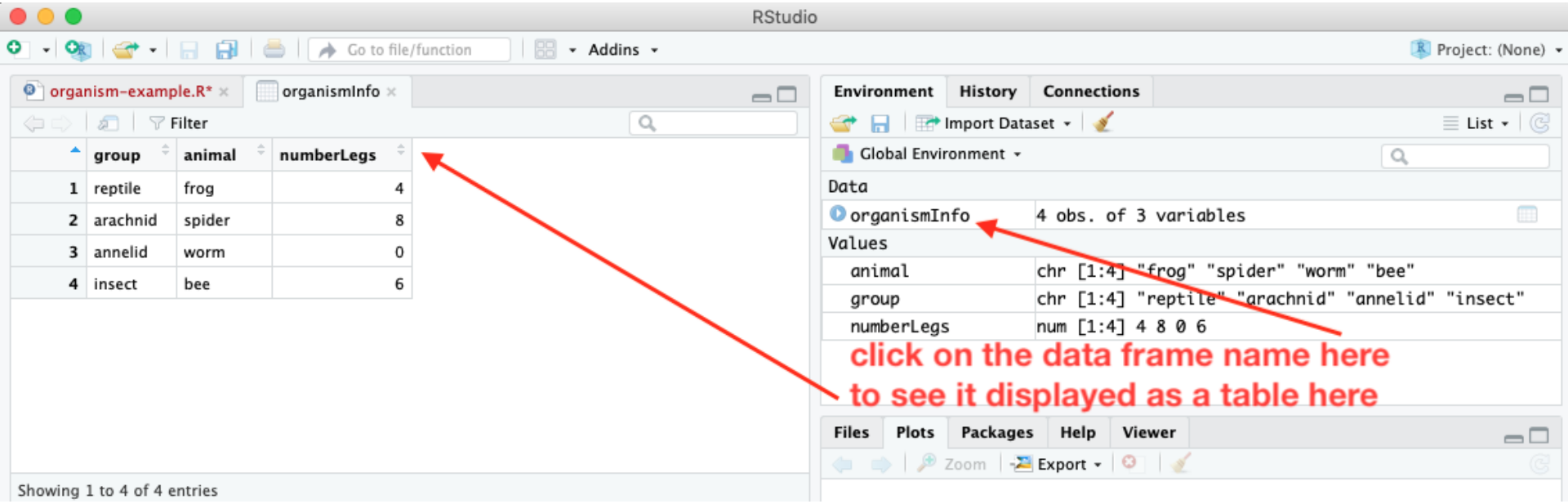
```
group <- c("reptile", "arachnid", "annelid", "insect") # vector of strings
animal <- c("frog", "spider", "worm", "bee")
number_legs <- c(4,8,0,6) # vector of numbers
```

- Then put the vectors into a data frame

```
organism_info <- data.frame(group, animal, number_legs)
```

- The vector names will be used for the column names

Viewing contents of a data frame



- Click on the name of the data frame in the Environment pane
- The contents will be displayed as a table

Referring to parts of a data frame

- Since the columns are like list items, we can refer to them by name:

```
organism_info$animal
```

- Individual cells can be referenced by:
  - row and column

    ```
    organism_info[2,1]
    ```

  - column name and position in column

    ```
    organism_info$animal[4]
    ```

Loading data from files

Tabular data in delimited files

- **Delimited files** are text files where values are separated by some text character and lines are separated by **newline** characters (i.e. "hard returns").
- Most common type of delimited file: **CSV** (comma separated values)
- Also used: TSV (tab separated values)
- Delimited files are much simpler than Excel files and are commonly used for archiving data.
- CSV files can be made by exporting from Excel

Reading delimited files into data frames

- There are several ways to read data from CSV files into R:
  - by a **file path** (platform-dependent)

```
my_data_frame <- read.csv("~/test.csv")
```
(Mac)

```
my_data_frame <- read.csv("c:\temp\test.csv")
```
(Windows)

  - by a **file-choosing dialog**

```
my_data_frame <- read.csv(file.choose())
```

  - by a **URL**

```
my_data_frame <=
read.csv(file="https://gist.githubusercontent.com/baskaufs/1a7a995c1b25d6e88b45/raw/4bb17ccc5c1e62c27627833a4f25380f27d30b35/t-test.csv")
```

Controlling the import process

- You can specify if the file has a **header row** (labels) using the **`header`** key (default value is TRUE)
- You can specify the **separator** if it's different from comma using the **`sep`** key (default value is comma)
- **`\t`** is the escaped value for a tab character
- Example:

```
nls_ds1 <- read.csv(file.choose(),
                    header = TRUE,
                    sep = "\t")
```

Practice: Nashville schools data

1. What does R do when column headers have spaces in them?
2. Display the values in the zip code column
3. How many values are there in the zip code column?
4. Calculate the number of students in each school by adding the values in the male and female columns
5. Calculate the fraction of students that are white in each school
6. Calculate the average fraction of white students by school

Factors in data frames

Factors

- A **factor** is a data structure for categorizing data.
- Its origin comes from **experimental design** terminology.
- In an experiment, each **category** into which an experimental trial can fall is called a **level**.
- Factors are sometimes called **grouping variables** because they are used to group observations.
- Factors may be required for some statistical tests and visualizations.

Factor example: science fair

water factor	height (cm)
wet	25
wet	21
dry	14
wet	13
dry	10
wet	18

- The water factor has two levels: wet and dry
- The height observations can be grouped by whether the experimental treatment was wet or dry

Factor example: creating factor values

- Create a vector of character strings and a vector of number values:

```
water_conditions <- c("wet", "wet", "dry", "wet", "dry", "wet")
height <- c(25, 21, 14, 13, 10, 18)
```

- Convert the strings into a factor

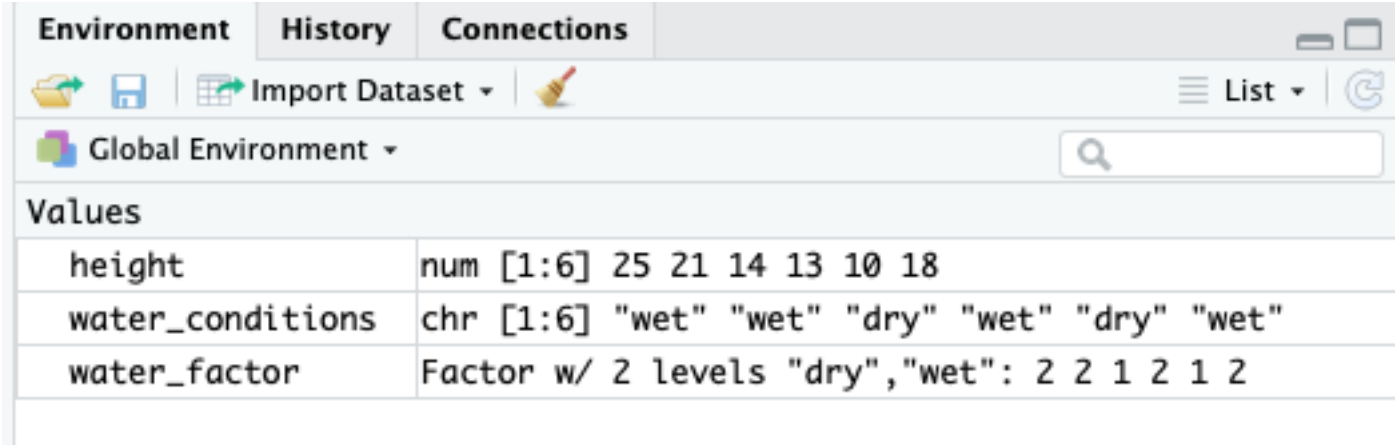
```
water_factor <- factor(water_conditions)
```

- Display the values of each data structure

```
water_conditions
water_factor
height
```

How to tell that a data structure is a factor

```
> water_conditions
[1] "wet" "wet" "dry" "wet" "dry" "wet"
> water_factor
[1] wet wet dry wet dry wet
Levels: dry wet
> height
[1] 25 21 14 13 10 18
>
```



- The main clue is that the **values of the levels** are listed.

Data frames and factors

- **character strings** imported from CSV files are automatically turned into **factors**
- **numbers** imported from CSV files are imported as **number vectors**
- This automatic behavior takes place because of the historical orientation of R towards statistics.
- The same behavior happens when data frames are built from individual vectors. (Investigate **`organism_info`** example)
- This can be good or bad depending on how you want to use the data.

Questions about the schools data

1. Is zip code a vector or a factor?
2. Should zip code be a vector or a factor?
3. Is school name a vector or a factor?
4. Should school name be a vector or a factor?

- Convert these data to the correct form using:

`factor()` turn a vector into a factor

`as.character()` turn a factor into a character vector

- How many levels of zip codes are there (vs. rows)?

Tibbles

- **Tibbles** are a special kind of data frame
- Tibbles are not built into R.
- Tibbles are part of the **tidyverse** (can be installed separately).
- Tibbles:
  - do not automatically convert character strings to factors when loading from files
  - are more relaxed about column headers
  - plus several other features

Loading tibbles

- Create a tibble from vectors:

```
library("tibble")
organism_tibble <- tibble(group, animal, number_legs)
```

- Load using **readr** package from tidyverse:

```
library(readr)
tibble_from_csv <- read_csv(file.choose())
```

- Load an **Excel** file into a tibble

```
library(readxl)
tibble_from_xl <- read_excel(file.choose())
```

Homework

- Homework problems related to the Nashville Schools data are in the R script for the lesson