Data structures

# 2

## R is designed to handle experimental data

- Although the basic unit of R is a vector, we usually handle data in **data frames**.
- A data frame is a set of observations of a set of variables – in other words, the outcome of an experiment.
- For example, we might want to analyse information about a set of patients. To start with, let's say we have ten patients and for each one we know their name, sex, age, weight and whether they give consent for their data to be made public.
- Load this data into a data frame called 'patients' in R:

```
source("05_patients.R")
```

## The patients data frame

- The 'patients' data frame has ten rows (observations) and seven columns (variables). The columns must all be equal lengths.

```
> patients
```

| | First_Name | Second_Name | Full_Name | Sex | Age | Weight | Consent |
|---|---|---|---|---|---|---|---|
| 1 | Adam | Jones | Adam Jones | Male | 50 | 70.8 | TRUE |
| 2 | Eve | Parker | Eve Parker | Female | 21 | 67.9 | TRUE |
| 3 | John | Evans | John Evans | Male | 35 | 75.3 | FALSE |
| 4 | Mary | Davis | Mary Davis | Female | 45 | 61.9 | TRUE |
| 5 | Peter | Baker | Peter Baker | Male | 28 | 72.4 | FALSE |
| 6 | Paul | Daniels | Paul Daniels | Male | 31 | 69.9 | FALSE |
| 7 | Joanna | Edwards | Joanna Edwards | Female | 42 | 63.5 | FALSE |
| 8 | Matthew | Smith | Matthew Smith | Male | 33 | 71.5 | TRUE |
| 9 | David | Roberts | David Roberts | Male | 57 | 73.2 | FALSE |
| 10 | Sally | Wilson | Sally Wilson | Female | 62 | 64.8 | TRUE |

- Let's see how we can construct this from scratch.

## Character, numeric and logical data types

- Each column is a vector, like previous vectors we have seen:

```
> firstName<- c("Adam", "Eve", "John", "Mary", "Peter", "Paul", "Joanna",
"Matthew", "David", "Sally")
> secondName<-c("Jones", "Parker", "Evans", "Davis", "Baker", "Daniels",
"Edwards", "Smith", "Roberts", "Wilson")
> age<-c(50, 21, 35, 45, 28, 31, 42, 33, 57, 62)
> weight<-c(70.8, 67.9, 75.3, 61.9, 72.4, 69.9, 63.5, 71.5, 73.2, 64.8)
> consent<-c(TRUE,TRUE,FALSE,TRUE,FALSE,FALSE,FALSE,TRUE,FALSE,TRUE)
```

- Each vector has a type, which we can see with the **mode** function:

```
> mode(firstName)
[ 1] "character"
> mode(age)
[ 1] "numeric"
> mode(weight)
[ 1] "numeric"
> mode(consent)
[ 1] "logical"
```

## Factors

- Character vectors are fine for some variables, like names
- But sometimes we have categorical data and we want R to recognise this.
- A factor is R's data structure for categorical data.

```
> sex<-c("Male", "Female", "Male", "Female", "Male", "Male", "Female",
"Male", "Male", "Female")
> sex
 [1] "Male"   "Female" "Male"   "Female" "Male"   "Male"   "Female" "Male"
"Male"   "Female"
> factor(sex)
 [1] Male   Female Male   Female Male   Female Male   Male   Female Male
Levels: Female Male
```

- R has converted the strings of the sex character vector into two **levels**, which are the categories in the data.
- Note the values of this factor are not character strings, but levels.
- We can use this factor to compare data for males and females.

## Creating a data frame (first attempt)

- We can construct a data frame from other objects:

```
> patients<-data.frame(firstName, secondName, paste(firstName,secondName),
    sex, age, weight, consent)
> patients
   firstName secondName paste.firstName..secondName.    sex age weight consent
1       Adam      Jones                  Adam Jones   Male  50   70.8    TRUE
2        Eve     Parker                 Eve Parker Female  21   67.9    TRUE
3       John      Evans                  John Evans   Male  35   75.3   FALSE
4       Mary      Davis                  Mary Davis Female  45   61.9    TRUE
5      Peter      Baker                 Peter Baker   Male  28   72.4   FALSE
6       Paul    Daniels                Paul Daniels   Male  31   69.9   FALSE
7     Joanna    Edwards              Joanna Edwards Female  42   63.5   FALSE
8    Matthew      Smith               Matthew Smith   Male  33   71.5    TRUE
9      David    Roberts               David Roberts   Male  57   73.2   FALSE
10     Sally     Wilson                Sally Wilson Female  62   64.8    TRUE
```

- The **paste** function joins character vectors together.
- We can access particular variables using the **dollar** operator:

```
> patients$age
 [1] 50 21 35 45 28 31 42 33 57 62
```

## Naming data frame variables

- R has inferred the names of our data frame variables from the names of the vectors or the commands (eg the paste command).
- We can name the variables after we have created a data frame using the **names** function, and we can use the same function to see the names:
- 
```
> names(patients)<-c("First_Name", "Second_Name", "Full_Name", "Sex",
"Age", "Weight", "Consent")
> names(patients)
[1] "First_Name"  "Second_Name" "Full_Name"   "Sex"         "Age"
"Weight"      "Consent"
```
- Or we can name the variables when we define the data frame:

```
> patients<-data.frame(First_Name=firstName, Second_Name=secondName,
Full_Name=paste(firstName,secondName), Sex=sex, Age=age, Weight=weight,
Consent=consent)
> names(patients)
[1] "First_Name"  "Second_Name" "Full_Name"   "Sex"         "Age"
"Weight"      "Consent"
```

## Factors in data frames

- When creating a data frame, R assumes all character vectors should be categorical variables and converts them to factors. This is not always what we want:

```
> patients$firstName
 [1] Adam    Eve     John    Mary    Peter   Paul    Joanna  Matthew David   Sally
Levels: Adam David Eve Joanna John Mary Matthew Paul Peter Sally
```

- We can avoid this by asking R not to treat strings as factors, and then explicitly stating when we want a factor by using **factor**:

```
> patients<-data.frame(First_Name=firstName, Second_Name=secondName,
Full_Name=paste(firstName,secondName), Sex=factor(sex), Age=age,
Weight=weight, Consent=consent, stringsAsFactors=FALSE)
> patients$Sex
 [1] Male   Female Male   Female Male   Male   Female Male   Male   Female
Levels: Female Male
> patients$First_Name
 [1] "Adam"    "Eve"     "John"    "Mary"    "Peter"   "Paul"    "Joanna"
"Matthew" "David"   "Sally"
```

## Storage modes & data types

- Data types - why care?
  - May get an undesired result if calculations are between numbers stored as different types
  - R will coerce data types when calculations between differing types are forced
    - If the operation is inappropriate, the calculation will fail.

      e.g.

      `> 2 + "2"`

      will fail as we cannot add a character string to integer!

## Matrices

**`matrix(..., ncol=…, nrow=…)`**

- Data frames are R's speciality, but R also handles matrices:

```
> e <- matrix(1:10, nrow=5, ncol=2)
> e
     [,1] [,2]
[1,]    1    6
[2,]    2    7
[3,]    3    8
[4,]    4    9
[5,]    5   10
> f <- matrix(1:10, nrow=2, ncol=5)
> f
     [,1] [,2] [,3] [,4] [,5]
[1,]    1    3    5    7    9
[2,]    2    4    6    8   10
> f %*% e
     [,1] [,2]
[1,]   95  220
[2,]  110  260
```

The `%*%` operator is the matrix multiplication operator, not the standard multiplication operator.

## Indexing data frames and matrices

Special cases:
a[*i*, ] i-th row
a[ ,*j*] j-th column

- You can index multidimensional data structures like matrices and data frames using commas. If you don't provide an index for either rows or columns, all of the rows or columns will be returned.

```
object [ rows , columns ]
```

```
> e[1,2]
[1] 6
> e[1,]
[1] 1 6
> patients[1,2]
[1] "Jones"
> patients[1,]
  First_Name Second_Name  Full_Name  Sex Age Weight Consent
1       Adam       Jones Adam Jones Male  50   70.8    TRUE
```

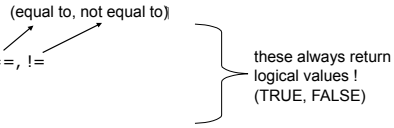
## Advanced indexing

- As values in R are really vectors, so indices are actually vectors, and can be numeric or logical:

```
> s <- letters[1:5]
> s[c(1,3)]
[1] "a" "c"
> s[c(TRUE, FALSE, TRUE, FALSE, FALSE)]
[1] "a" "c"
> a<-1:5
> a<3
[1]  TRUE  TRUE FALSE FALSE FALSE
> s[a<3]
[1] "a" "b"
> s[a>1 & a<3]
[1] "b"
> s[a==2]
[1] "b"
```

## Operators

- arithmetic
  +, -, *, /, ^
- comparison
  <, >, =<, >=, ==, !=
- logical
  !, &, |, xor




## Exercise

- Create the patients data frame using the instructions in the slides.
- Add three new variables to your data frame: country, continent, and height. Make up the data. Make country a character vector but continent a factor.
- Try the **summary** function on your data frame. What does it do? How does it treat vectors (numeric, character, logical) and factors? (What does it do for matrices?)
- Use logical indexing to select the following patients:
  - Patients under 40
  - Patients who give consent to share their data
  - Men who weight as much or more than the average European male (70.8 kg)

## Logical indexing answers

- Patients under 40:
```
> patients[patients$Age<40,]
```
- Patients who give consent to share their data:
```
> patients[patients$Consent==TRUE,]
```
- Men who weigh as much or more than the average European male (70.8 kg):
```
> patients[patients$Sex=="Male" & patients$Weight<=70.8,]
```