University of Zurich[UZH]

MAKERERE UNIVERSITY

Data Analysis with R:
Lecture Slides (all)

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Lecture Slides for Day 1

Goals of the course

To be able to...

- import data sets to R
- describe data with R
- apply basic statistical tests in R
- some ideas for more advanced statistical tools ...
- simulate a data set similar to own research

General remarks

Course schedule:

- Starting at 9:00am / 9:30am (?)
- Tea breaks in between
- Lunch break
- Teaching until 4.30pm ($\sim$ 5pm)

Optaining a certificate is conditional on:

- active participation in class
- attending at least 75 % of the course (lecture & exercises)
- short final exam (format to be defined)

Getting to know each other

- My name is ...
- I am doing a Master / a PhD in ...
- I hope to learn in this course how to ....
- My personal goal for this course is ...

How do we reach these goals

- hands on exercises with R:
  - `chickwts`
  - `ToothGrowth`
  - `bacteria`
  - `perulung`
  - ... and others.
- interactive discussions & student's present their own solutions
- ask us a lot of questions but also ask google for help!
- group work
- short motivational lectures

Get started with data set: chickwts

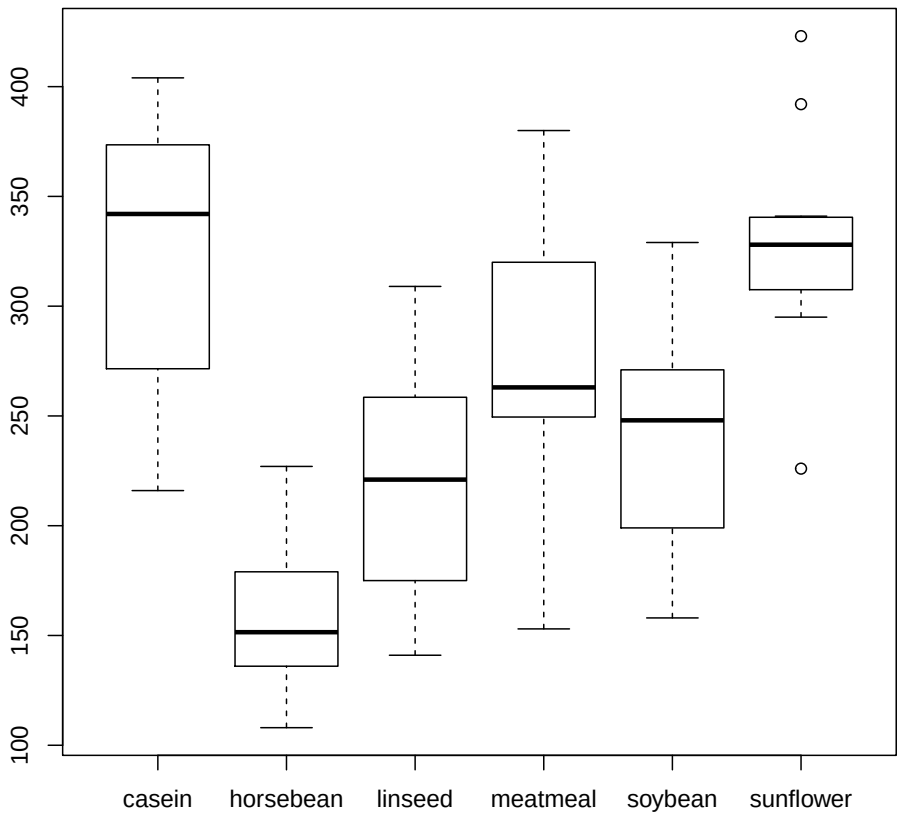
An experiment was conducted to measure and compare the effectiveness of various feed supplements on the growth rate of chickens.

```
# load data set "chickwts"
data(chickwts)
# the head(...) function shows the first 6 observations
head(chickwts)

##   weight      feed
## 1    179 horsebean
## 2    160 horsebean
## 3    136 horsebean
## 4    227 horsebean
## 5    217 horsebean
## 6    168 horsebean

# FUNCTION - open bracket - DATA SET / VARIABLE - close bracket
```

Ideas for plotting the data

Ideas for plotting the data

```
# use x axis to show the categorical variable (feed),
# y axis to represent the continuous variable (weight)
# boxplot (y.cont.variable ~ x.cat.variable, data = dataset)
# ?boxplot
boxplot(weight ~ feed, data = chickwts)
```



Ideas for analysing the data

Ideas for analysing the data

```
anova <- aov(weight ~ feed, data = chickwts)
summary(anova)

##             Df Sum Sq Mean Sq F value   Pr(>F)
## feed         5 231129   46226   15.37 5.94e-10 ***
## Residuals   65 195556    3009
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

summary(aov(weight ~ feed, data = chickwts))

##             Df Sum Sq Mean Sq F value   Pr(>F)
## feed         5 231129   46226   15.37 5.94e-10 ***
## Residuals   65 195556    3009
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

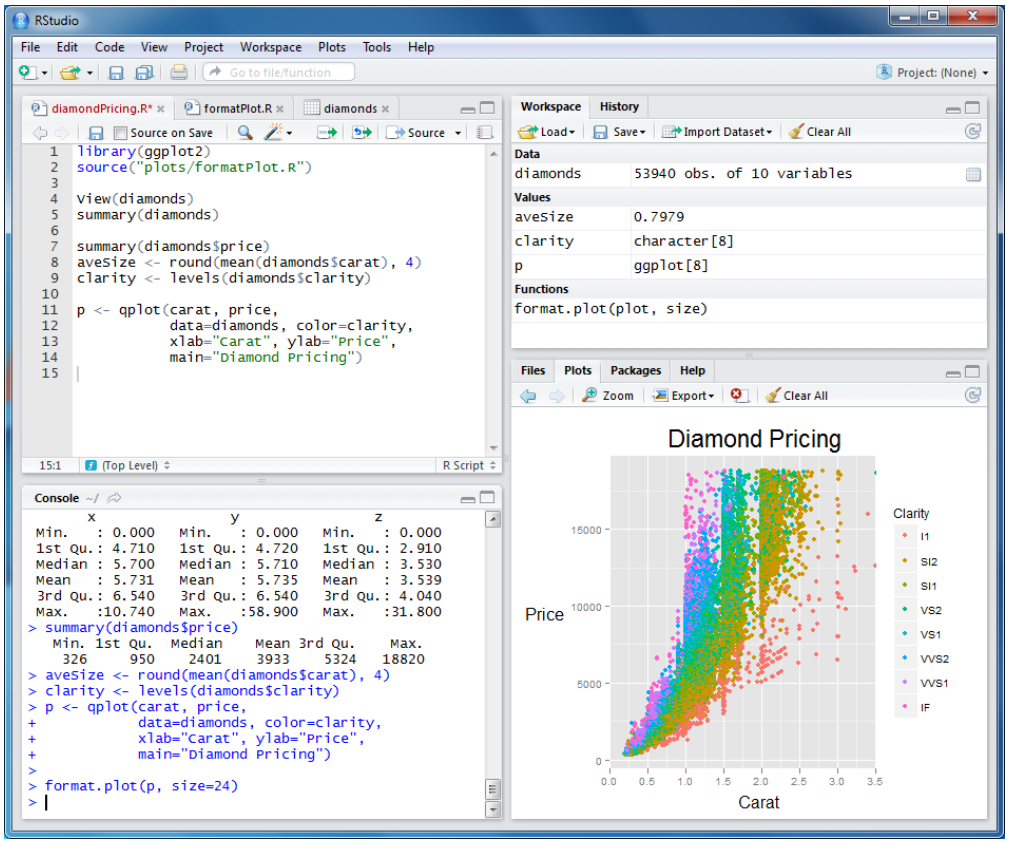
Functionalities in R and RStudio

A hands on example

```
x <- c(0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10)
y <- c(20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30)
plot(x, y)
```

Functionalities in R and RStudio

- Source
- Console
- Environment, History, Files
- Files, Plots, Packages, Help



Good housekeeping!

- Define manually a new folder called **RCourse** in your personal documents on your personal computer
- Know in which directory you are

```
getwd()

## [1] "/home/mburi/ownCloud/git/DataAnalysisWithR/Lectures"
```

- Set directory path

```
# back- and forslash is dependent on the system
setwd("C:/Users/muriel/Documents/RCourse/")
setwd("C:\\Users\\muriel\\Documents\\RCourse\\")
```

- Always clean up before starting with new R-Script

```
rm(list=ls()) # empty workspace, delete previously saved variables
```

How to get help in R

```
?chickwts
?boxplot
```

Also, have a look at the examples at the end of the help pages.

Exercise 1

A data frame in R: `chickwts`

chickwts[ROWS , COLUMNS]

	weight	feed
1	179	horsebean
2	160	horsebean
3	136	horsebean
4	227	horsebean
5	217	horsebean
6	168	horsebean
7	108	horsebean
8	124	horsebean
9	143	horsebean
10	140	horsebean
11	309	linseed
12	229	linseed
13	181	linseed

chickwts[6, 1]

	weight	feed
1	179	horsebean
2	160	horsebean
3	136	horsebean
4	227	horsebean
5	217	horsebean
6	168	horsebean
7	108	horsebean
8	124	horsebean
9	143	horsebean
10	140	horsebean
11	309	linseed
12	229	linseed
13	181	linseed

chickwts[11, 2]

Rows and columns of a data frame: `chickwts`

Values of ...

```
# ... all columns of sixth observation:
chickwts[6, ]

# ... all columns of sixth to eleventh observation:
chickwts[c(6:11), ]

# ... all columns of sixth, eleventh and twentieth observation:
chickwts[c(6, 11, 20), ]

# ... all rows of first column (weight):
chickwts[ , 1]

# ... all rows of second column (feed):
chickwts[ , 2]

# or use the "$" sign as a reference to column "feed":
chickwts$feed
```

Lecture Slides for Day 2

What is a data frame in R?

A data frame is used for storing a list of vectors of equal length. For example, the following variable `df` is a data frame containing three vectors `n`, `s`, `b`.

```
n <- c(2, 3, 5)
s <- c("aa", "bb", "cc")
b <- c(TRUE, FALSE, TRUE)
df <- data.frame(n, s, b) # df is a data frame
```

Following are the characteristics of a data frame:

- The column names should be non-empty.
- The row names should be unique.
- Each column should contain same number of data items.

Data frame in R

```
a <- c(1, 2, 3, 4)
a

## [1] 1 2 3 4

data.frame(a)

##   a
## 1 1
## 2 2
## 3 3
## 4 4

b <- c("d", "h", "h", "d")
dat <- data.frame(a, b)
dat

##   a b
## 1 1 d
## 2 2 h
## 3 3 h
## 4 4 d
```

Data frame in R: How to add a variable (var)

```
my.var <- c(1.3, 1.5, 1.8, 2.4)
# use "$" to refer to the additional vector variable
dat$my.var1 <- my.var
dat$my.var2 <- my.var
dat
```

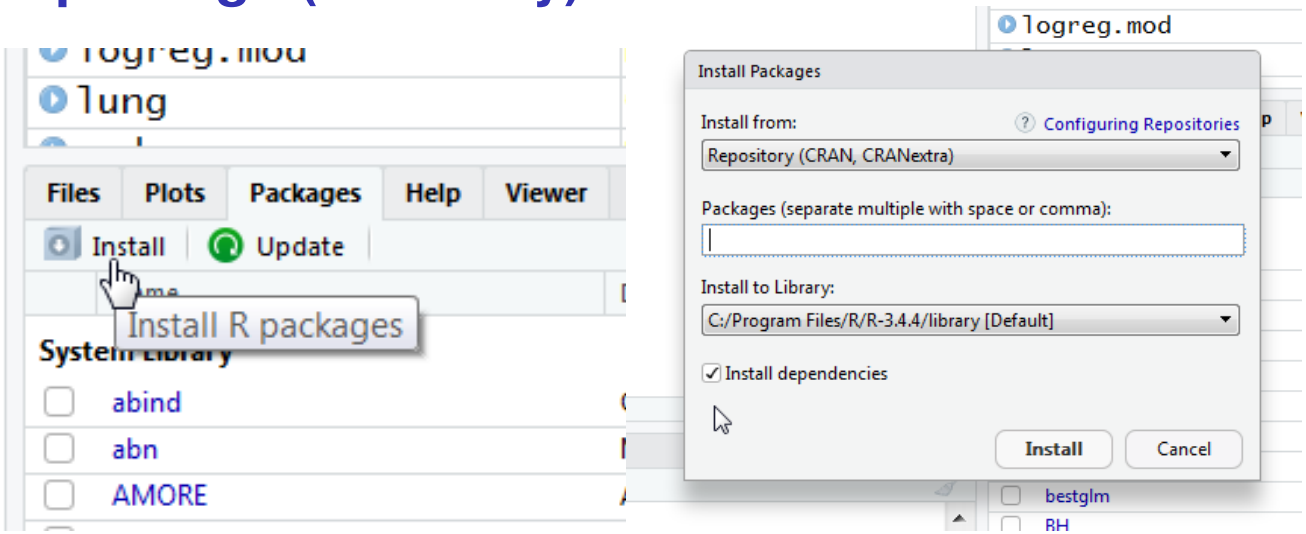
```
##   a b my.var1 my.var2
## 1 1 d     1.3     1.3
## 2 2 h     1.5     1.5
## 3 3 h     1.8     1.8
## 4 4 d     2.4     2.4
```

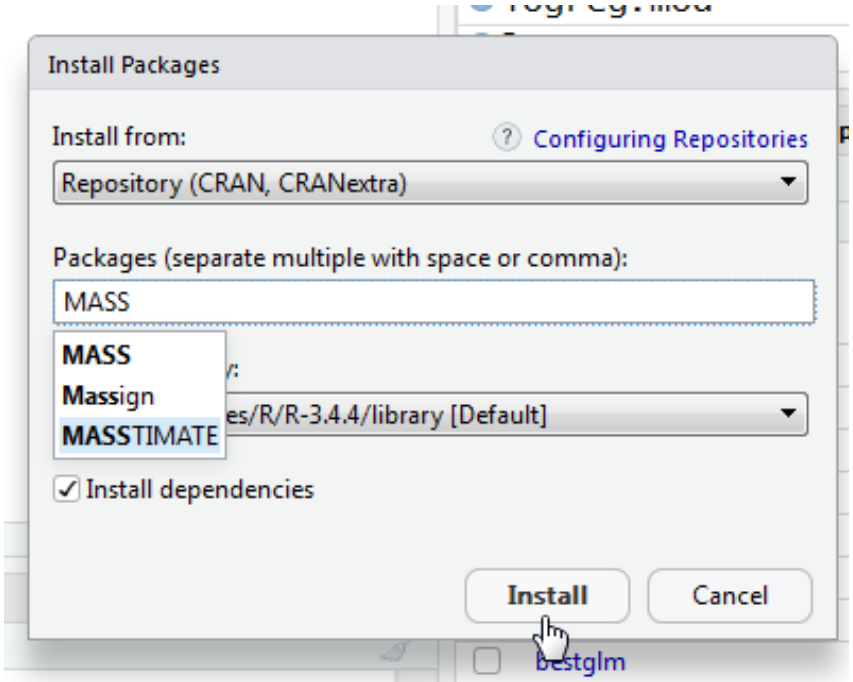
```
# What is the dimension (number of rows and columns) of our data frame?
dim(dat) # 4 rows and 3 columns
```

```
## [1] 4 4
```

Exercise 2

How to install a package (manually) in R





Using R is like cooking ...

Get into the kitchen	Change working directory
Get specialist electric tools into your kitchen (e.g. blender, ice-cream maker, etc.)	Install packages
Switch on your specialist electric tools	Load packages using the "library" function
Bring in your ingredients	Import data and save to R data frames
Check your ingredients	Use the function "summary" and basic tables to check your data for missing or implausible values (e.g. a number in a variable where "yes" or "no" are expected
Chop things up (if required)	Split or filter data
Cook, using general and specialist tools	Carry out further descriptive and test statistics

How to install a package in R

```r
# INSTALL package (only done ONCE!)
install.packages("MASS")
# LOAD package (whenever you use something from it!)
library("MASS")
data(bacteria)
?bacteria
```

Exercise 3

How to google for getting help in R

- Google for **select observations in R**.

Creating and assigning objects in R

Objects are assigned values using $<-$,
an arrow formed out of $<$ and $-$. For example, the following command assigns the value 1 to the object `a`.

```
a <- 1 # ALWAYS use "gets" assignment operator!

# a = 1 # DO NOT USE the equal sign as the assignment operator!
```

After this assignment, the object `a` contains the value 1. Another assignment to the same object will change the content.

```
a <- 5
```

Examples of assigned objects: single number

```
a <- 1
b <- 2
c <- a + b # c = 3
c
```

```
## [1] 3
```

Examples of assigned objects: vector

```
a <- c(1, 2, 3, 4, 5)
b <- 1
c <- a + b
c
```

```
## [1] 2 3 4 5 6
```

Examples of assigned objects: model

```
anova_model <- aov(weight ~ feed, data = chickwts)
summary(anova_model)

##             Df Sum Sq Mean Sq F value   Pr(>F)
## feed         5 231129   46226   15.37 5.94e-10 ***
## Residuals   65 195556    3009
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Examples of assigned objects: data frame

```
bac <- bacteria
str(bac) # $ week: int  0 2 4 11 0 2 6 11 0 2 ...

## 'data.frame': 220 obs. of  6 variables:
##  $ y   : Factor w/ 2 levels "n","y": 2 2 2 2 2 2 1 2 2 2 ...
##  $ ap  : Factor w/ 2 levels "a","p": 2 2 2 2 1 1 1 1 1 1 ...
##  $ hilo: Factor w/ 2 levels "hi","lo": 1 1 1 1 1 1 1 1 2 2 ...
##  $ week: int  0 2 4 11 0 2 6 11 0 2 ...
##  $ ID  : Factor w/ 50 levels "X01","X02","X03",..: 1 1 1 1 2 2 2 2 3 3 ...
##  $ trt : Factor w/ 3 levels "placebo","drug",..: 1 1 1 1 3 3 3 3 2 2 ...

bac_sub <- subset(bac, week == 2)
str(bac_sub) # $ week: int  2 2 2 2 2 2 2 2 2 2 ...

## 'data.frame': 44 obs. of  6 variables:
##  $ y   : Factor w/ 2 levels "n","y": 2 2 2 2 2 2 1 2 2 2 ...
##  $ ap  : Factor w/ 2 levels "a","p": 2 1 1 2 2 1 1 2 2 2 ...
##  $ hilo: Factor w/ 2 levels "hi","lo": 1 1 2 2 2 2 1 1 2 1 ...
##  $ week: int  2 2 2 2 2 2 2 2 2 2 ...
##  $ ID  : Factor w/ 50 levels "X01","X02","X03",..: 1 2 3 4 5 6 7 8 9 11 ...
##  $ trt : Factor w/ 3 levels "placebo","drug",..: 1 3 2 1 1 2 3 1 1 1 ...
```

Structure of a R objects

The `str` function displays the structure of an R object. One line for each ”basic” structure is displayed.

```
## 'data.frame': 44 obs. of  6 variables:
##  $ y   : Factor w/ 2 levels "n","y": 2 2 2 2 2 2 1 2 2 2 ...
##  $ ap  : Factor w/ 2 levels "a","p": 2 1 1 2 2 1 1 2 2 2 ...
##  $ hilo: Factor w/ 2 levels "hi","lo": 1 1 2 2 2 2 1 1 2 1 ...
##  $ week: int  2 2 2 2 2 2 2 2 2 2 ...
##  $ ID  : Factor w/ 50 levels "X01","X02","X03",..: 1 2 3 4 5 6 7 8 9 11 ...
##  $ trt : Factor w/ 3 levels "placebo","drug",..: 1 3 2 1 1 2 3 1 1 1 ...
```

Exercise 4

Data types in R

- numeric

```
data(ToothGrowth)
ToothGrowth$len[1:6]

## [1]  4.2 11.5  7.3  5.8  6.4 10.0

class(ToothGrowth$len[1:6])

## [1] "numeric"
```

- integers

```
bacteria$week[1:6]

## [1]  0  2  4 11  0  2

class(bacteria$week[1:6])

## [1] "integer"
```

- (un/ordered) factor

```
chickwts$feed[1:6]

## [1] horsebean horsebean horsebean horsebean horsebean horsebean
## Levels: casein horsebean linseed meatmeal soybean sunflower

levels(chickwts$feed)[1:3]

## [1] "casein"    "horsebean" "linseed"
```

Data types in R: Ordered Factors

Ordinal variables are represented as ordered factors:

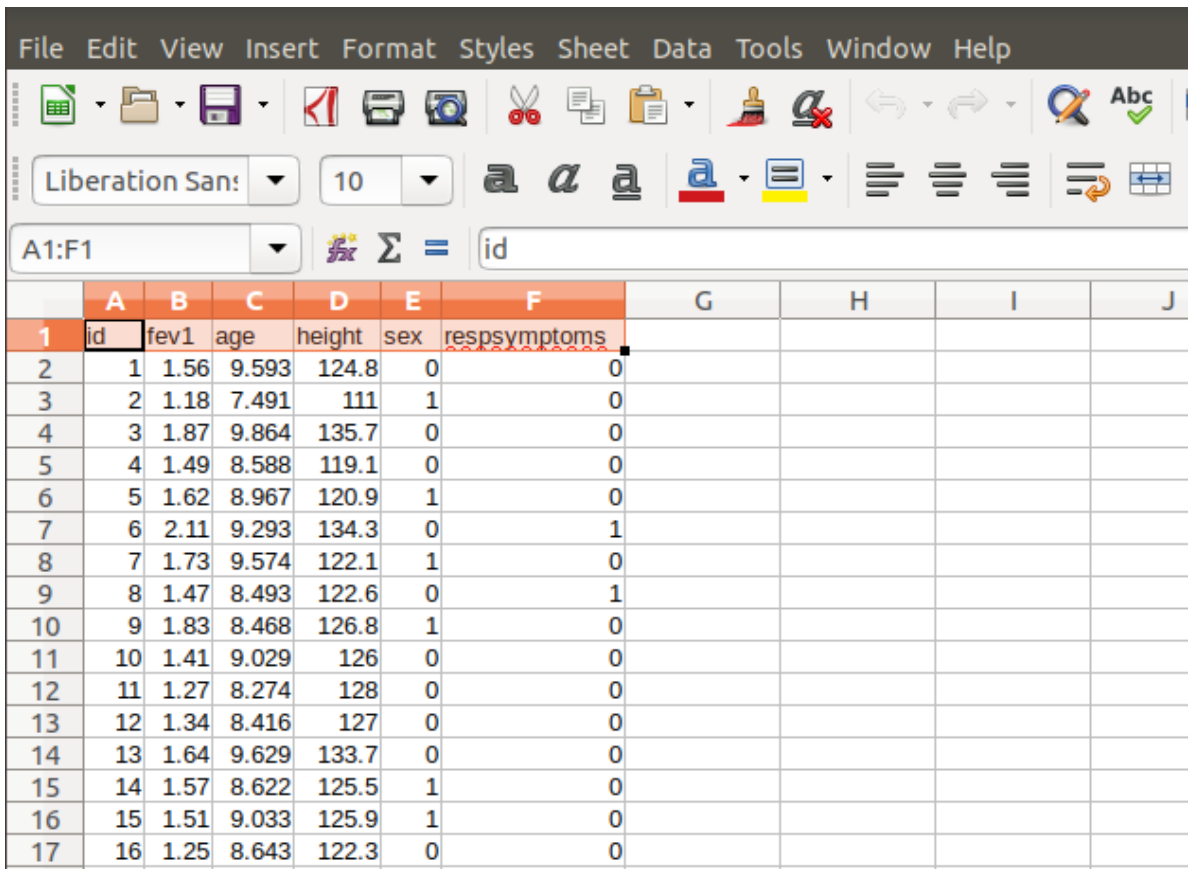
```
bac_growth <- c("none", "+", "++", "+", "+++", "+", "none") # vector
bac_growth <- factor(bac_growth, levels = c("none", "+", "++", "+++"),
                     order = TRUE)
bac_growth

## [1] none +    ++   +    +++  +    none
## Levels: none < + < ++ < +++

#
mood <- c("OK", "Well", "Super", "Super", "Don't ask", "OK") # vector
mood <- factor(mood, levels = c("Don't ask", "Well", "OK", "Super"),
               order = TRUE)
mood

## [1] OK        Well      Super     Super     Don't ask OK
## Levels: Don't ask < Well < OK < Super
```

Exercise 5

Exercise 6

Rules for importing data into R (from Excel)

- First row of excel sheet contains **variable names**: `y, ap, hilo, week, ID, trt`.
- Columns of excel sheet represent **variables**.
- Rows of excel sheet represent **observations per individual** (except for the first row).



	A	B	C	D	E	F	G	H	I	J
1	id	fev1	age	height	sex	respsymptoms				
2	1	1.56	9.593	124.8	0	0				
3	2	1.18	7.491	111	1	0				
4	3	1.87	9.864	135.7	0	0				
5	4	1.49	8.588	119.1	0	0				
6	5	1.62	8.967	120.9	1	0				
7	6	2.11	9.293	134.3	0	1				
8	7	1.73	9.574	122.1	1	0				
9	8	1.47	8.493	122.6	0	1				
10	9	1.83	8.468	126.8	1	0				
11	10	1.41	9.029	126	0	0				
12	11	1.27	8.274	128	0	0				
13	12	1.34	8.416	127	0	0				
14	13	1.64	9.629	133.7	0	0				
15	14	1.57	8.622	125.5	1	0				
16	15	1.51	9.033	125.9	1	0				
17	16	1.25	8.643	122.3	0	0				

Rules for naming variables

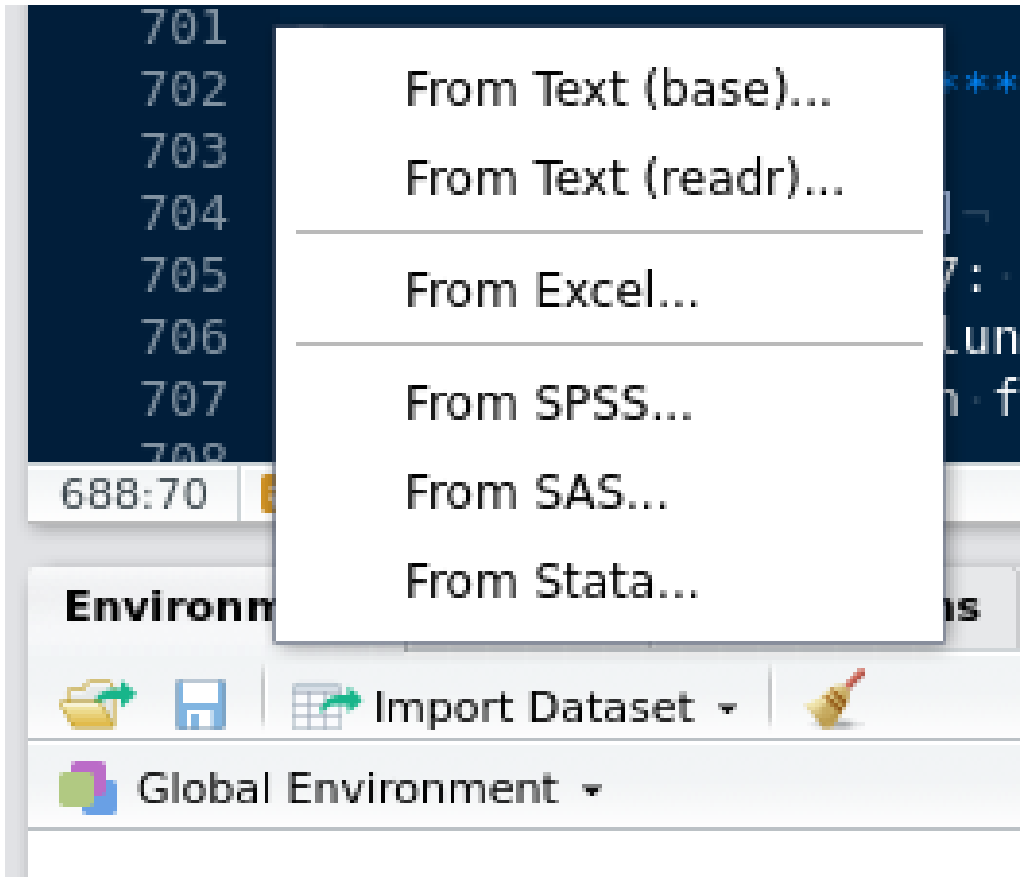
Variable names should ...

- start with a letter (not a number):
  `y, ap, hilo, week, ID, trt`
- longer variables names should be separated with dots:
  `time.in.weeks`
- do not use special characters, such as /, #, @, &, $\star$, ...

How to import external data files into R?

- $>$ Import Dataset $>$ **From Text (base)...** $>$ CSV Files (.csv)

  or
- $>$ Import Dataset $>$ **From Excel...**



How to import external data files into R?

- Environment (upper right corner)
- > Import Dataset > **From Text (base)...** > CSV Files (.csv)

```
perulung_ems <- read.csv("perulung_ems.csv", row.names = 1,
                         sep = ";")
lung <- data.frame(perulung_ems)
```

- > Import Dataset > **From Text (base)...** > Text Files (.txt)
- > Import Dataset > **From Excel...** > Excel Files (.xlsx)

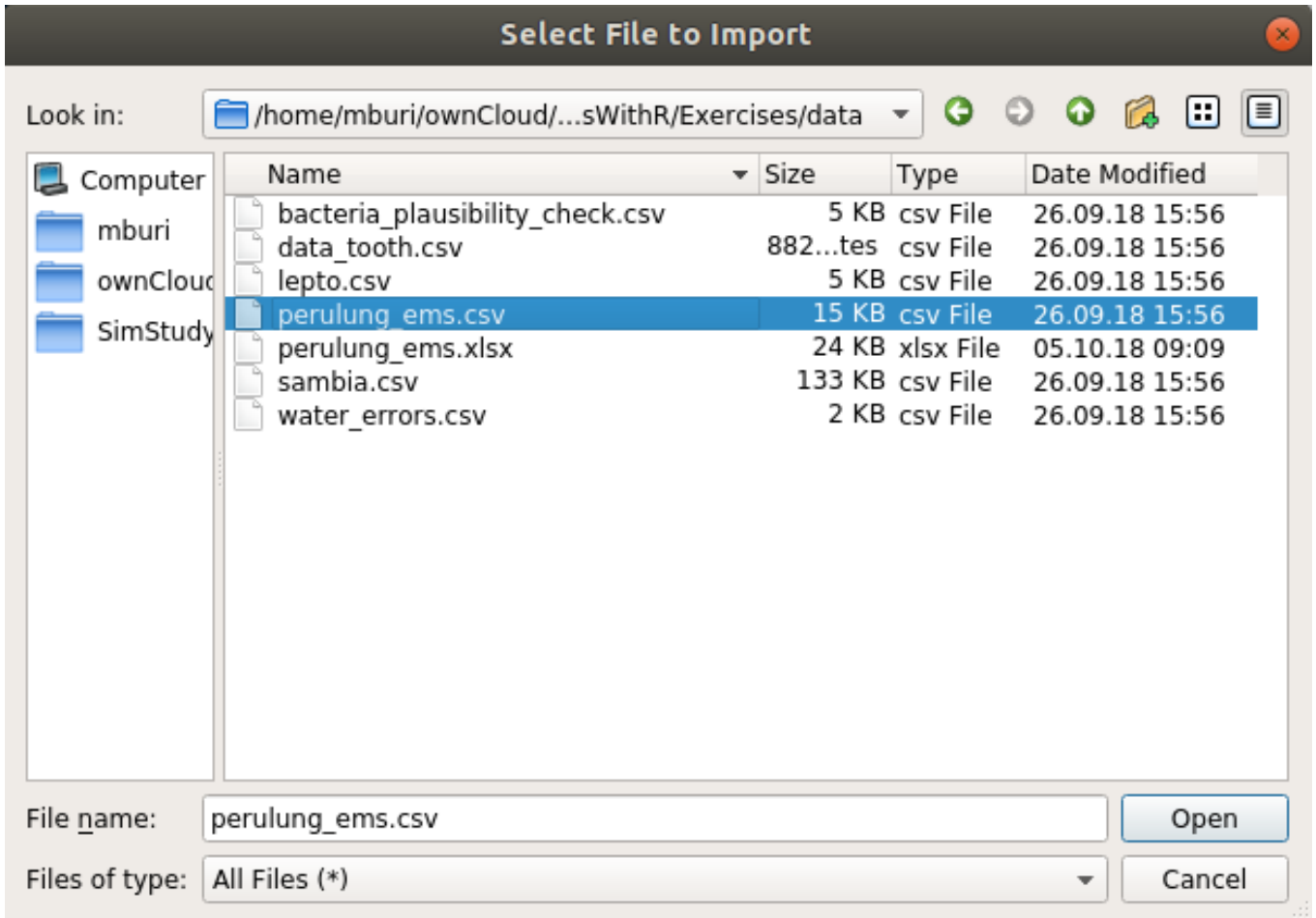
```
install.packages("readxl")
library("readxl")
perulung_ems <- read_excel("perulung_ems.xlsx")
lung <- data.frame(perulung_ems)
head(lung)
```

How to import .txt and .csv files into R? (1/2)

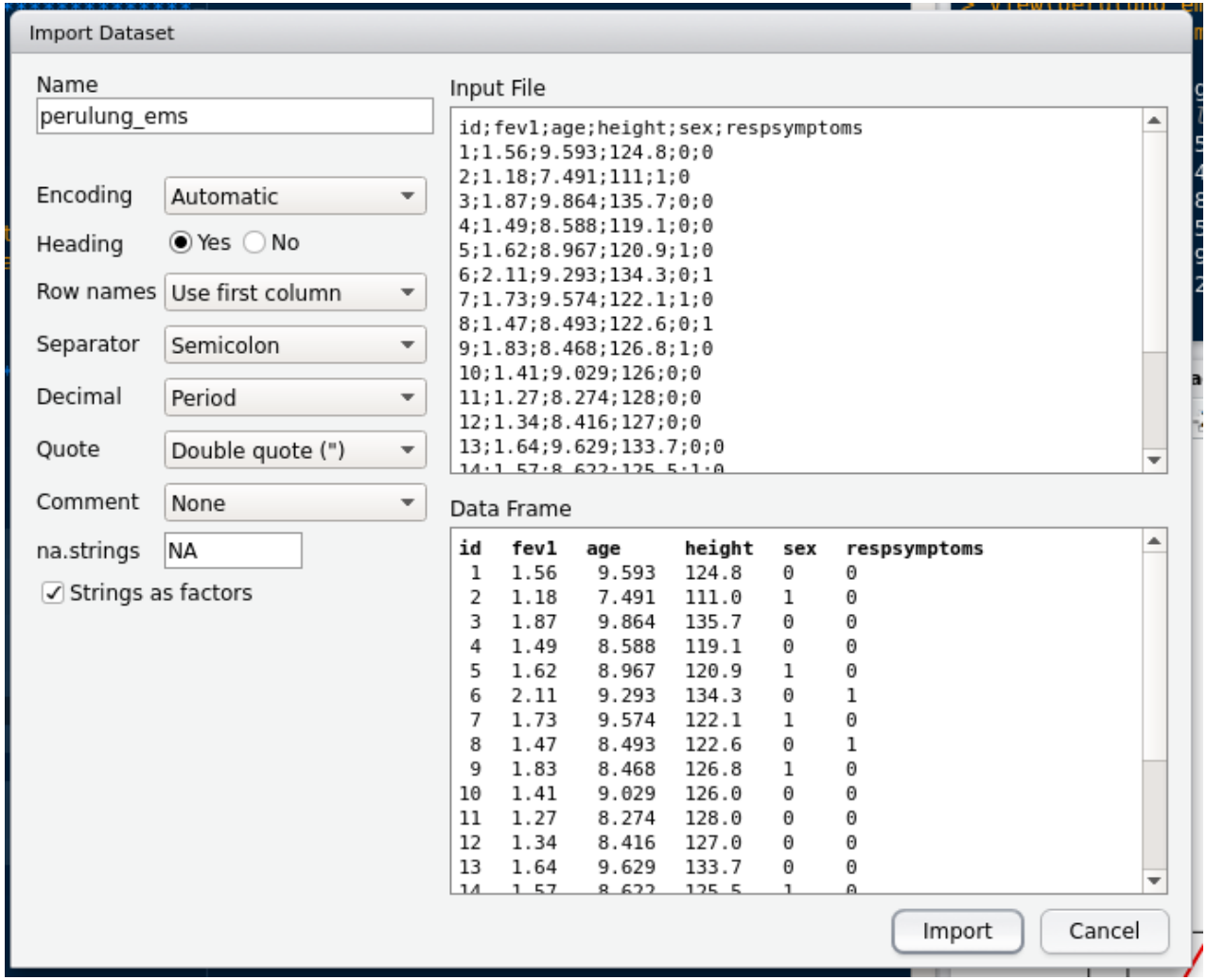
- Environment (upper right corner)
- $>$ Import Dataset $>$ From Text (base)... $>$ CSV Files (.csv)

How to import .txt and .csv files into R? (1/2)

- Environment (upper right corner)
- > Import Dataset > From Text (base)... > CSV Files (.csv)



How to import .txt and .csv files into R? (2/2)



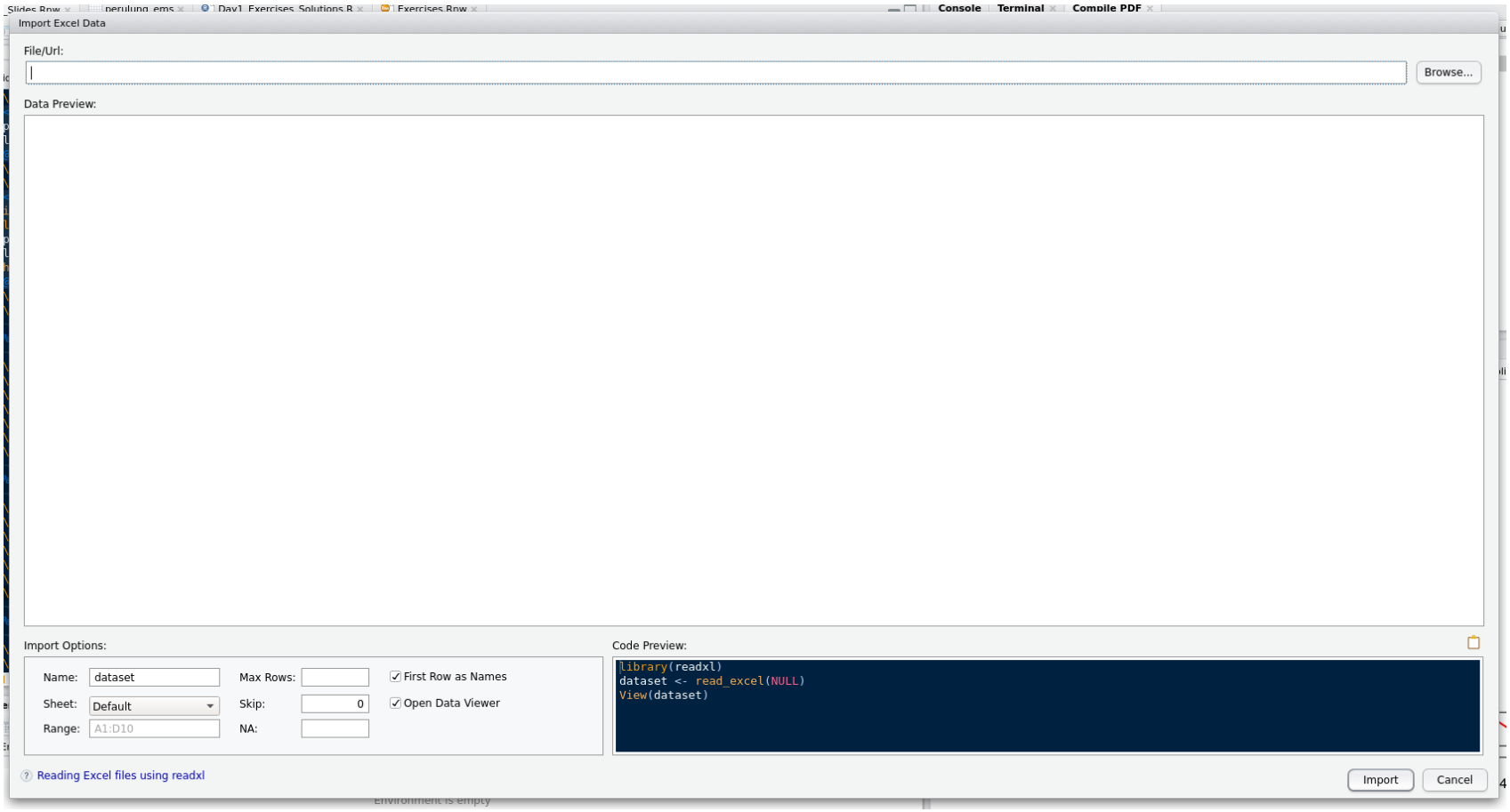

```
perulung_ems <- read.csv("perulung_ems.csv", row.names = 1,
                         sep = ";")
lung <- data.frame(perulung_ems)
```

How to import .xlsx files into R? (1/3)

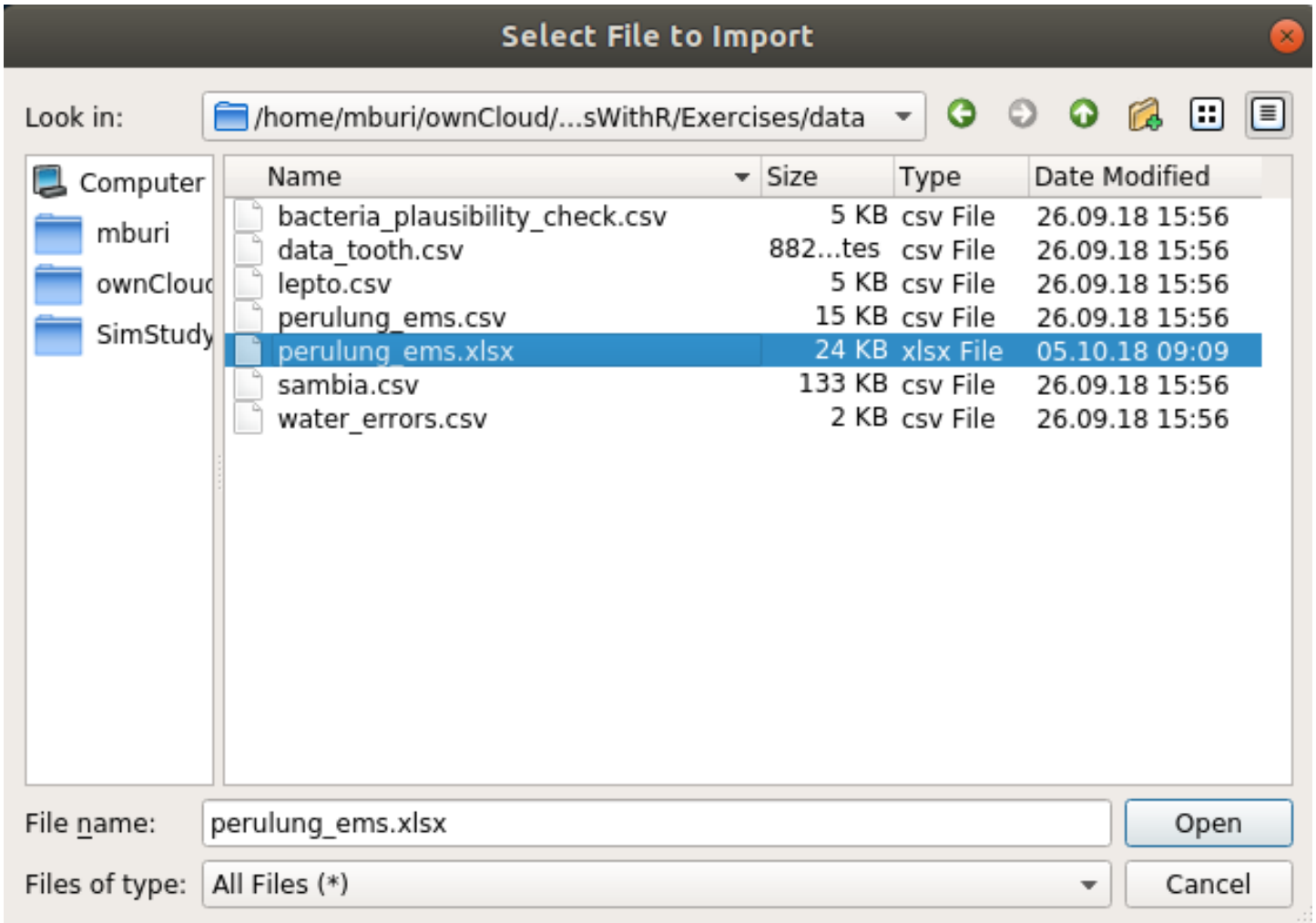
- Environment (upper right corner)
- $>$ Import Dataset $>$ From Excel... $>$ Excel Files (.xlsx)

How to import .xlsx files into R? (1/3)

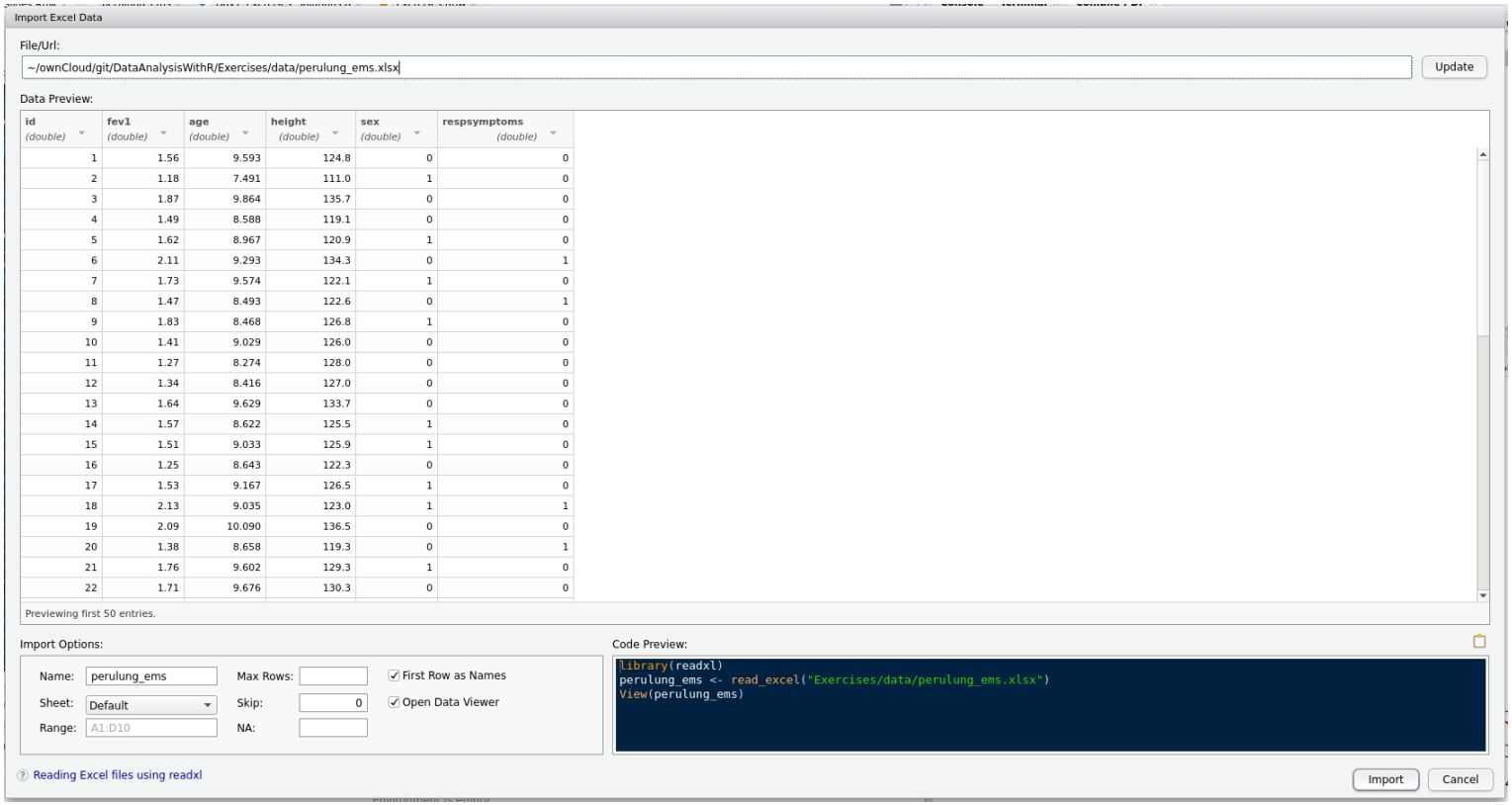
- Environment (upper right corner)
- $>$ Import Dataset $>$ From Excel... $>$ Excel Files (.xlsx)



How to import .xlsx files into R? (2/3)



How to import .xlsx files into R? (3/3)




```
perulung_ems <- read_excel("perulung_ems.xlsx")
lung <- data.frame(perulung_ems)
head(lung)
```

Exercise 7: perulung

Data from a study of lung function among children living in a deprived suburb of Lima, Peru. Data taken from Kirkwood and Sterne, 2nd edition.
Variables:

- `fev1`: in liter, "forced expiratory volume in 1 second" measured by a spirometer. This is the maximum volume of air which the children could breath out in 1 second
- `age`: in years
- `height`: in cm
- `sex`: 0 = girl, 1 = boy
- `respsymp`: respiratory symptoms experienced by the child over the previous 12 months

Lecture Slides for Day 3