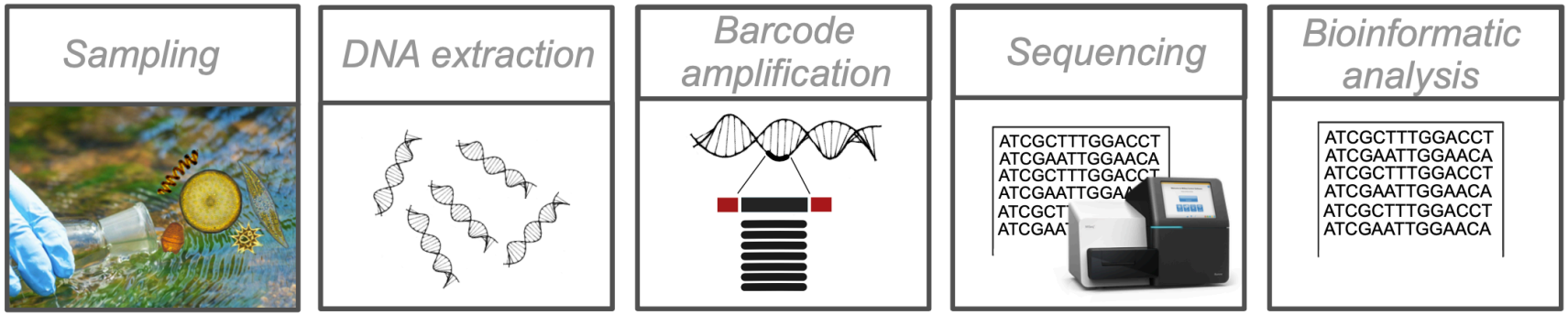
Ecological analysis of metabarcoding data

Introduction to R

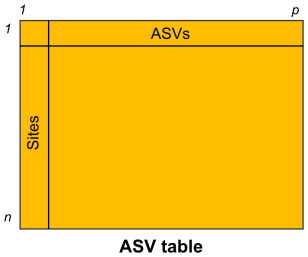
Clarisse Lemonnier

Previously in BIOLAWEB…

Theory on all the steps of the metabarcoding pipeline

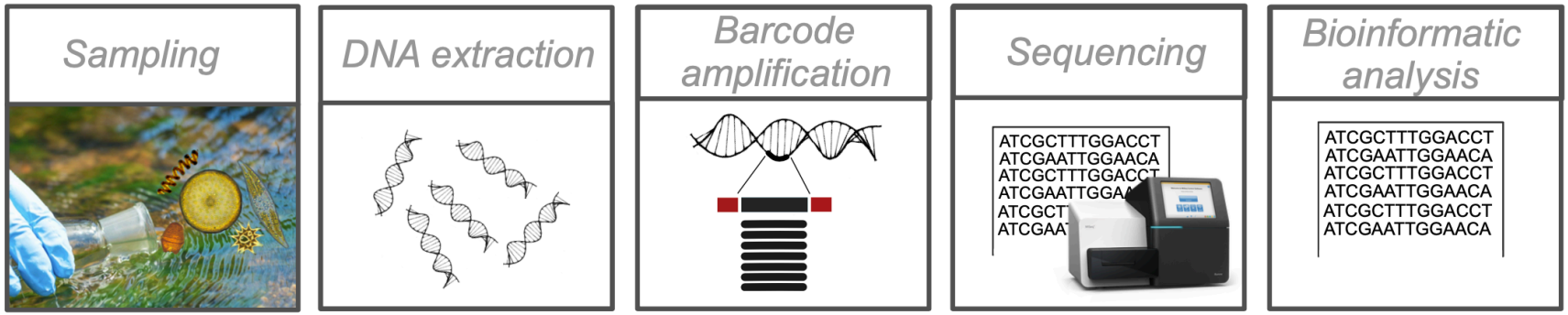


Raw data

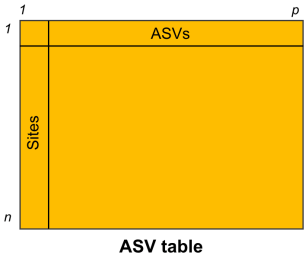


+ taxonomy

Now :
Ecological analysis of metabarcoding data



Raw data

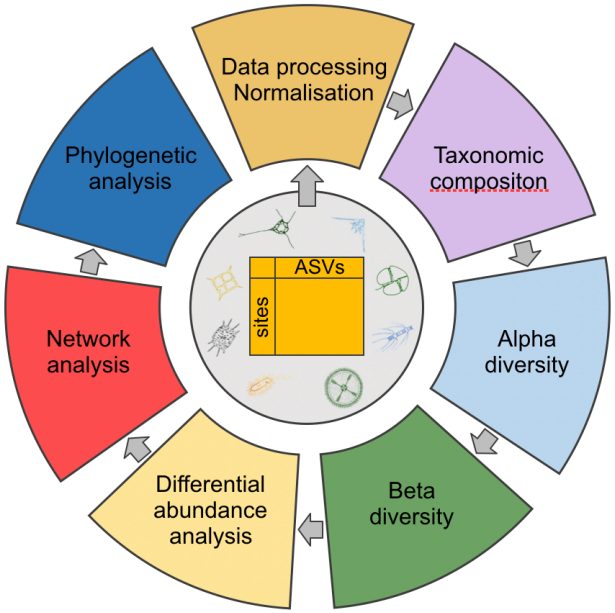


+ taxonomy

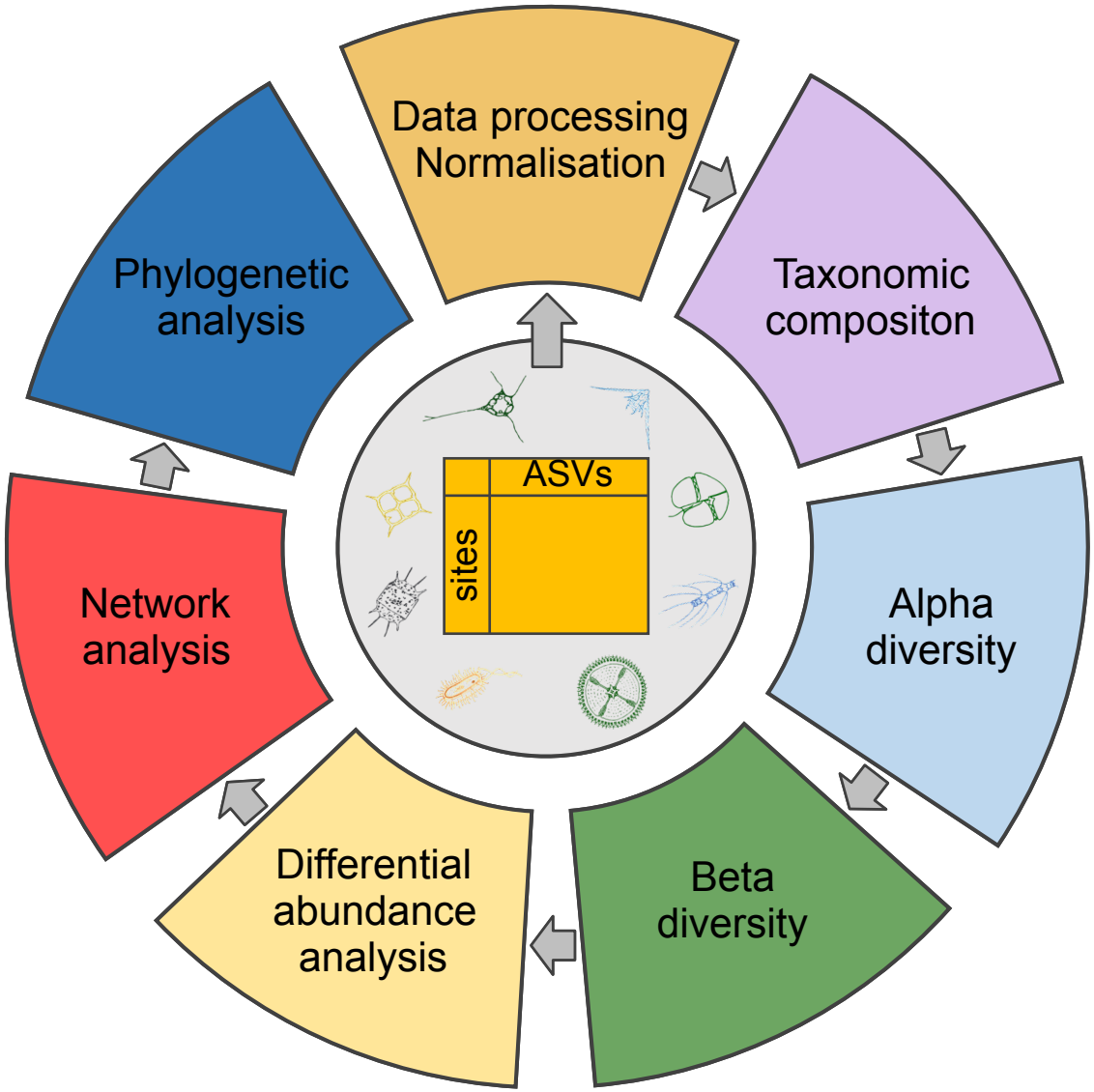
Theory

+

Practical sessions



Statistical analysis workflow from metabarcoding data



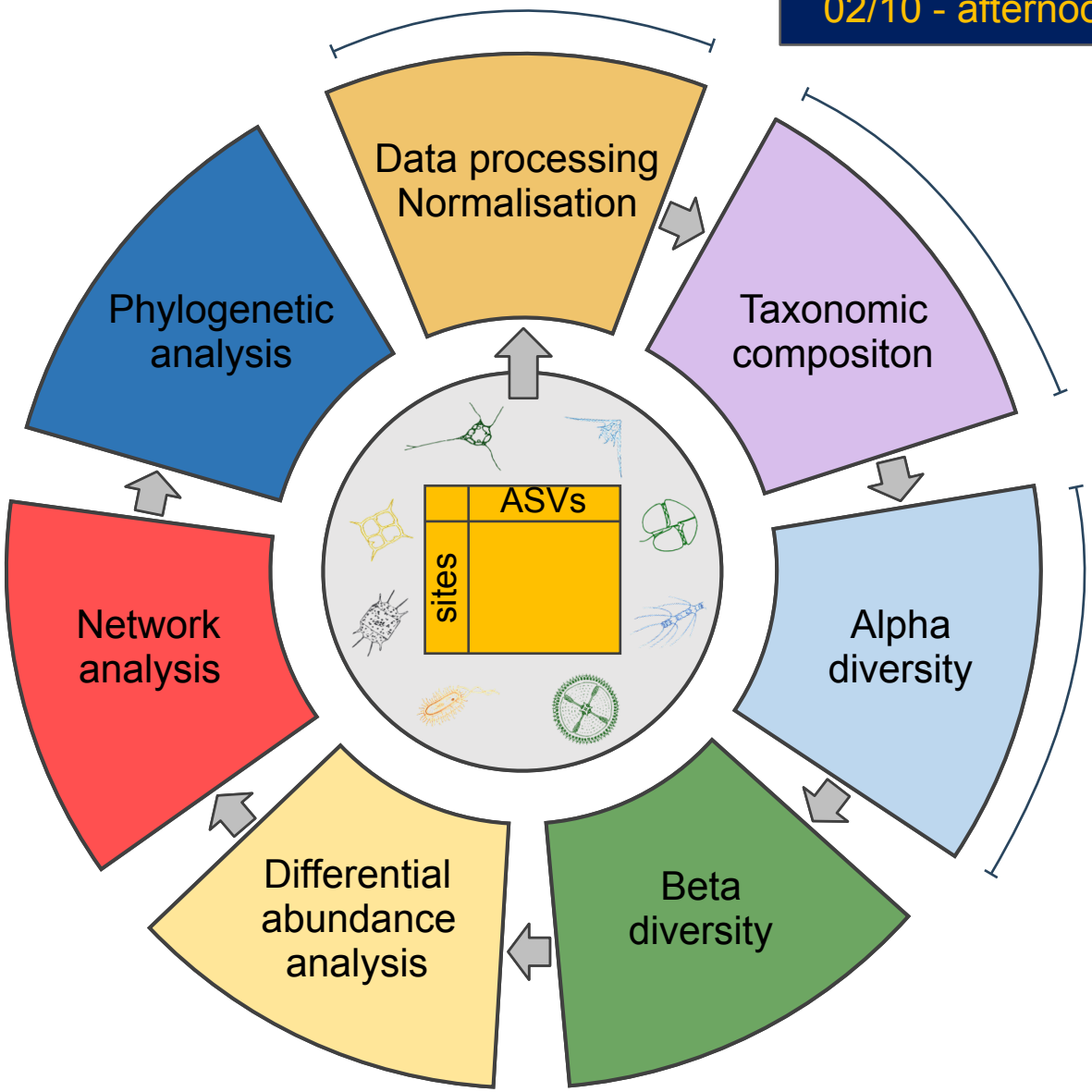
Microbial community analysis

Statistical analysis workflow from metabarcoding data

02/10 - afternoon

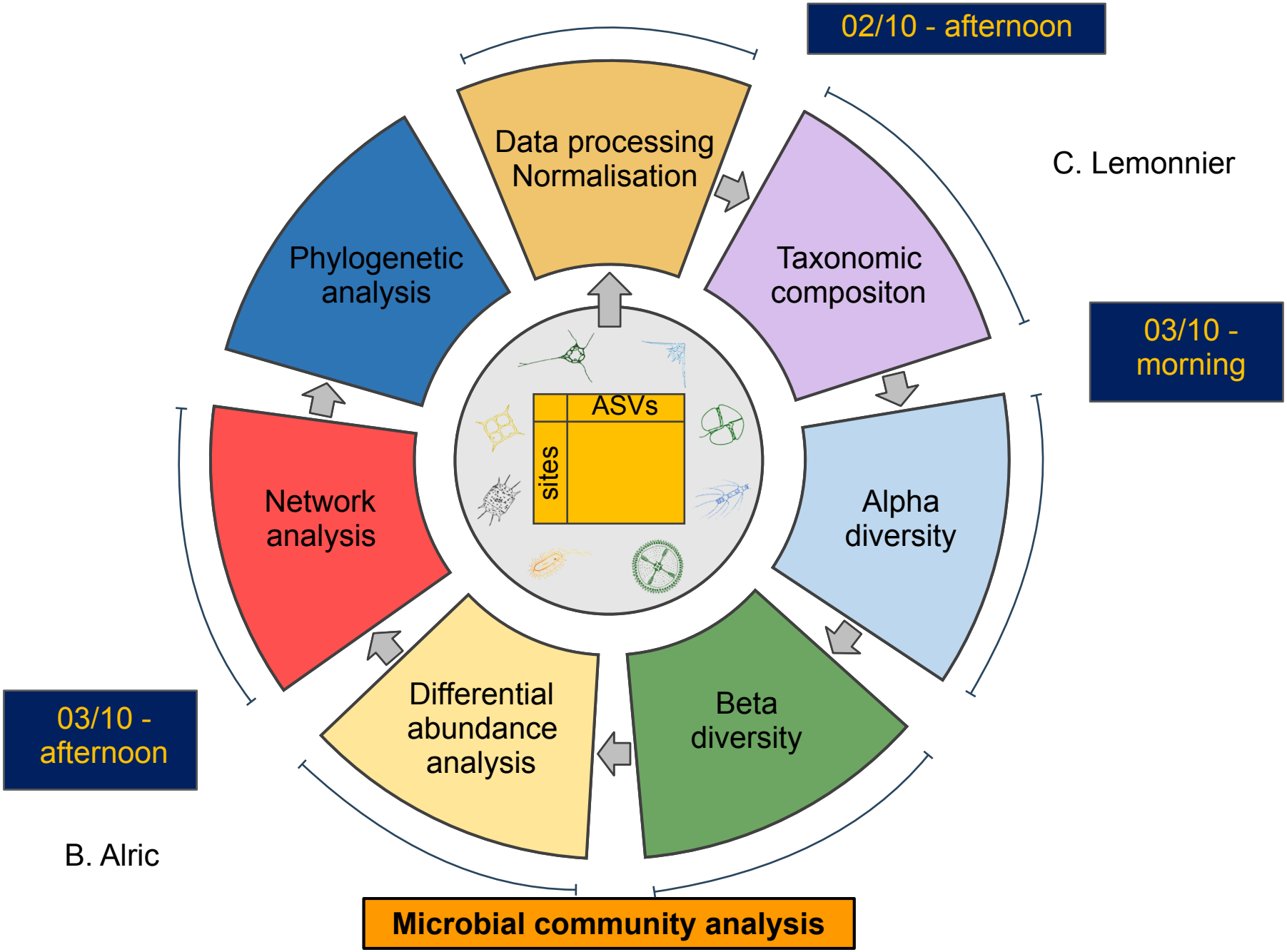
C. Lemonnier

03/10 - morning

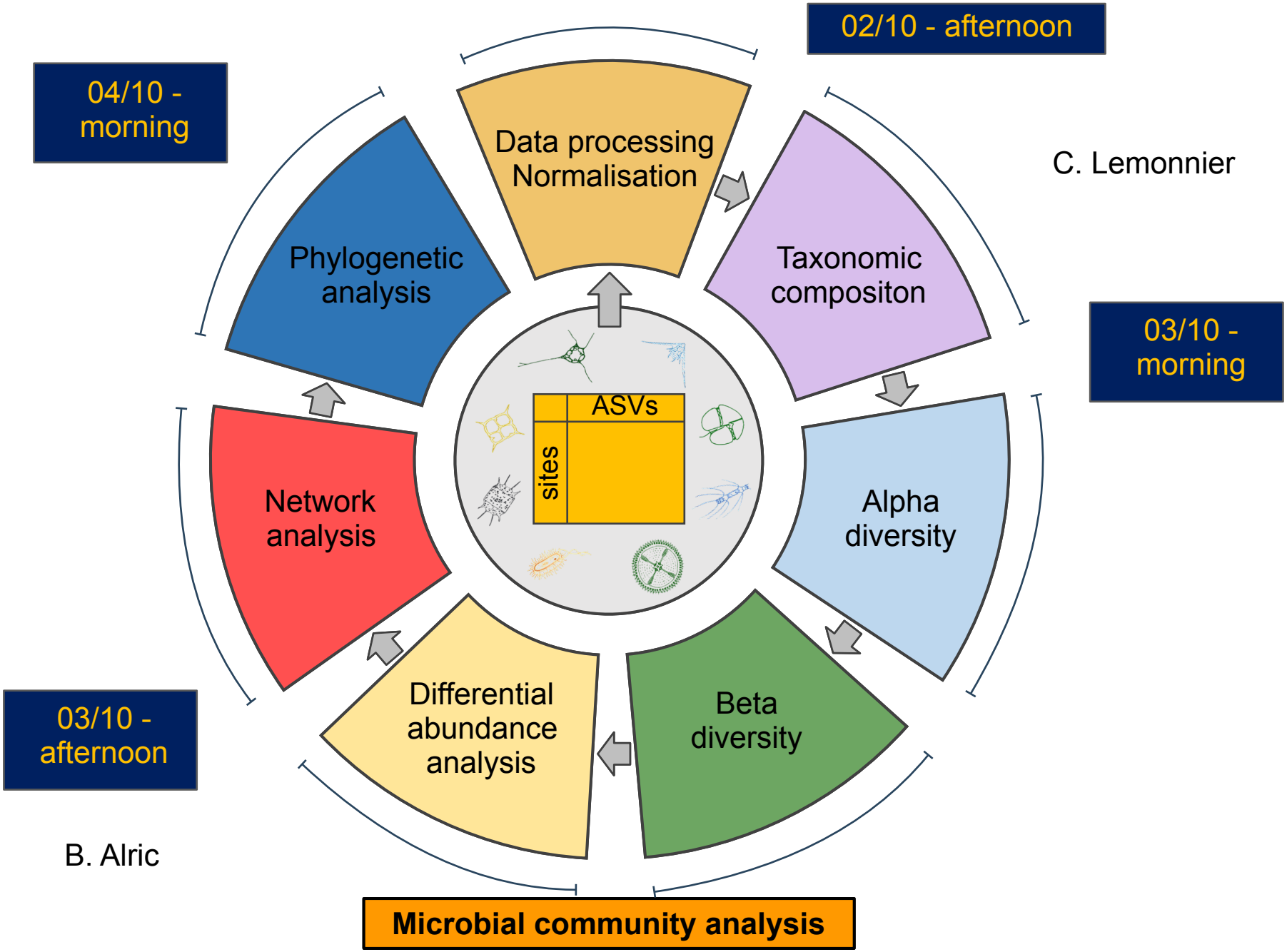


Microbial community analysis

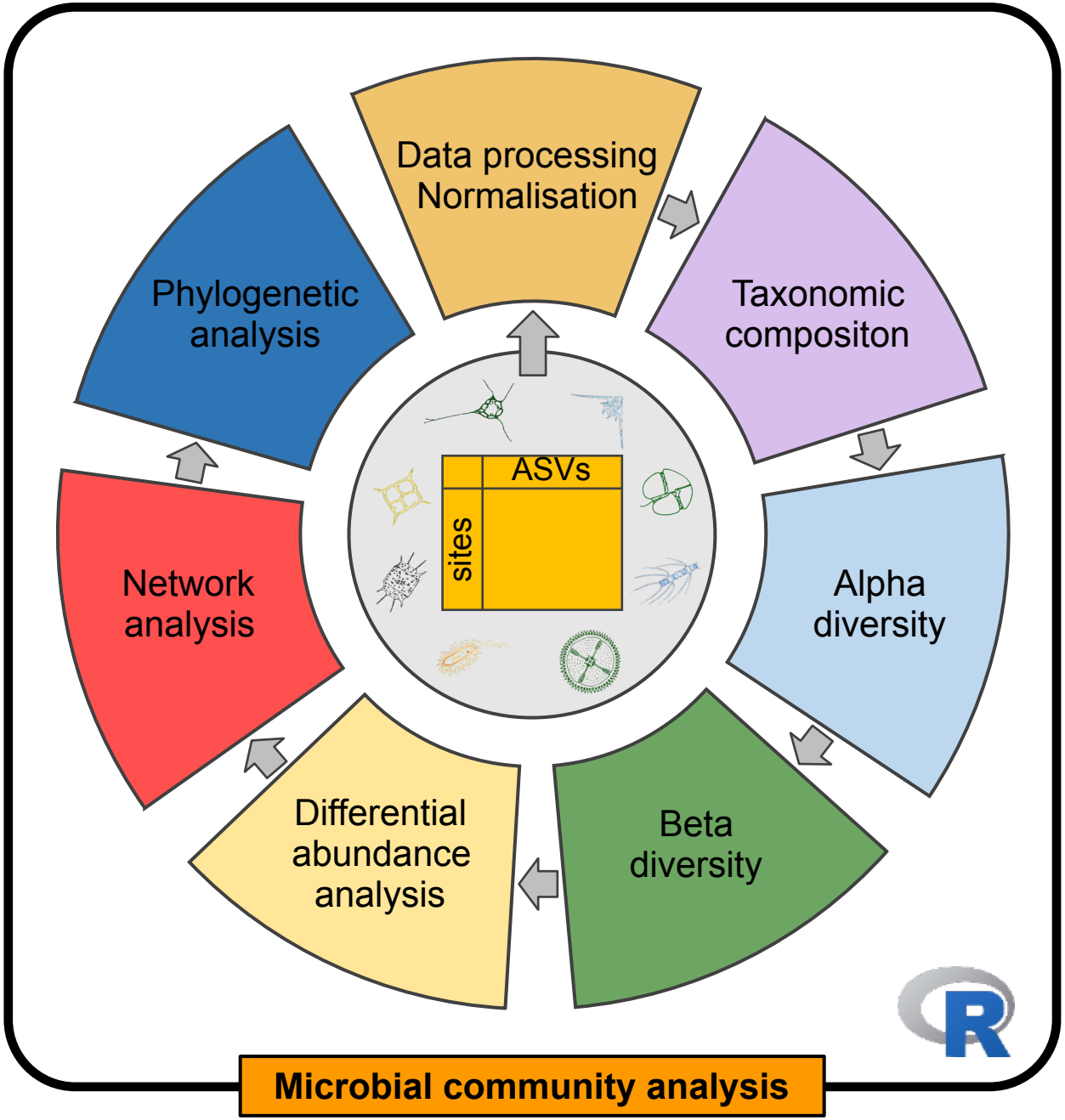
Statistical analysis workflow from metabarcoding data

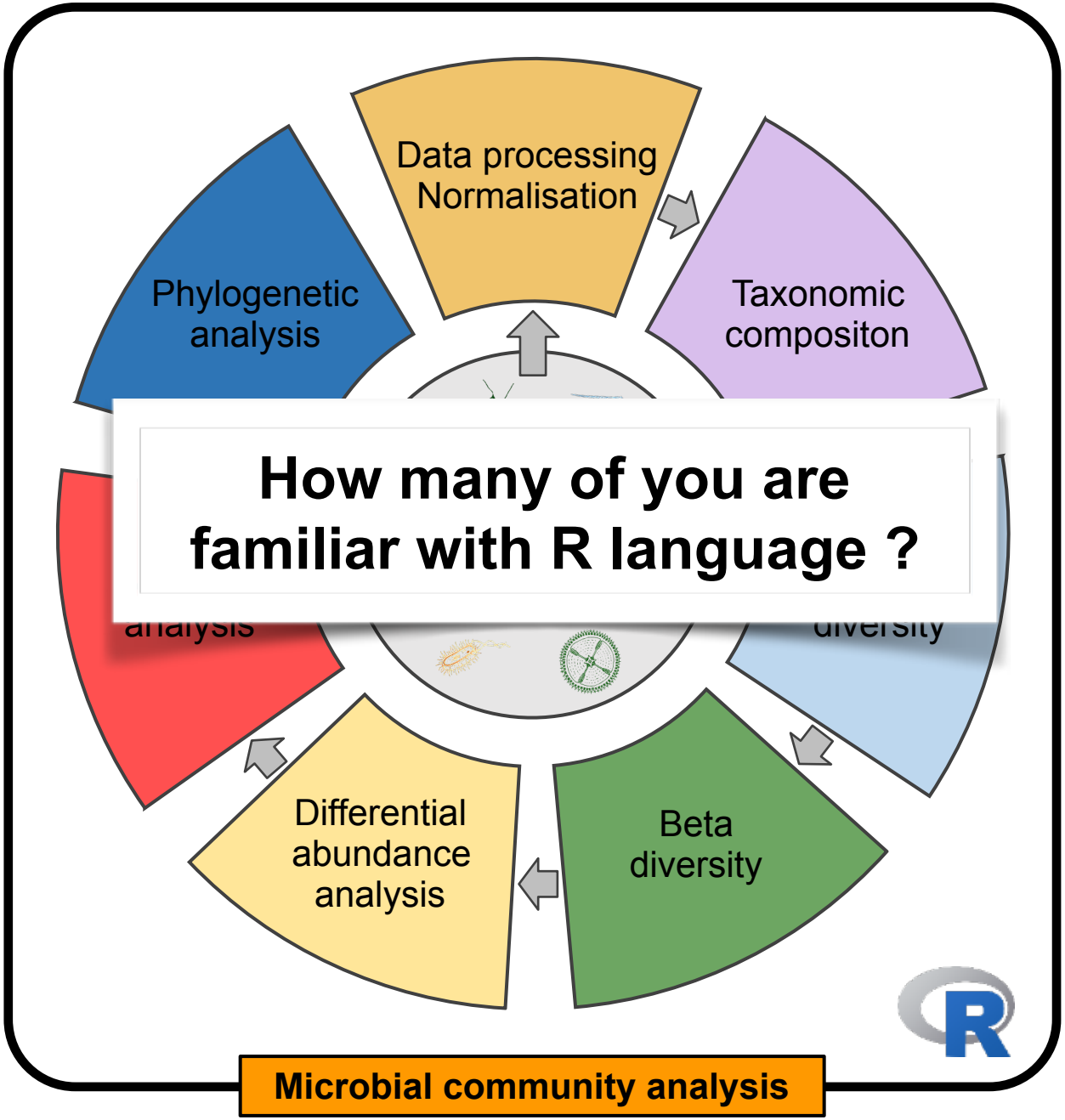


Statistical analysis workflow from metabarcoding data



Statistical analysis workflow from metabarcoding data




Data processing
Normalisation
Taxonomic
compositon
Beta
diversity
Differential
abundance
analysis
Phylogenetic
analysis
How many of you are familiar with R language ?
Microbial community analysis

```
Call:
lm(formula = y ~ ., data = data)

Residuals:
    Min      1Q  Median
-8.7859 -2.0085  0.00
                          9.7121

Coefficients:
            Estimat        Error
(Intercept)  1.3831       .24566
x1           5.29776       12483
x2           1.61055       5518
x3           0.44947       19
groupB       1.87978     0.16
---
Signif. codes:  0 ‘***’ 0.001 ‘*
                                  01 ‘*’
                                  ‘.’ 0.1 ‘ ’ 1

Residual standard error: 2.817 on 995 degrees of freedom
Multiple R-squared:  0.7882,    Adjusted R-squared:  0.7873
F-statistic: 925.6 on 4 and 995 DF,  p-value: < 2.2e-16
```

What is R ?

- R is an **open source** programming **language**
- It was designed for **statistical computing**, **data analysis** and **graphic display**
- It works in all operating system
- It is widely used in academic research

```
Call:
lm(formula = y ~ ., data = data)

Residuals:
    Min      1Q  Median
-8.7859 -2.0085  0.00
                          9.7121

Coefficients:
            Estimat        Error
(Intercept)  1.3831       .24566
x1           5.29776       12483
x2           1.61055       5518
x3           0.44947
groupB       1.87978     0.16
---
Signif. codes:  0 ‘***’ 0.001 ‘*
                                  01 ‘*’
                                          .’ 0.1 ‘ ’ 1

Residual standard error: 2.817 on 995 degrees of freedom
Multiple R-squared:  0.7882,    Adjusted R-squared:  0.7873
F-statistic: 925.6 on 4 and 995 DF,  p-value: < 2.2e-16
```

What can we do with R?

Analytics

Basic mathematics

Statistical tests

Big data analysis

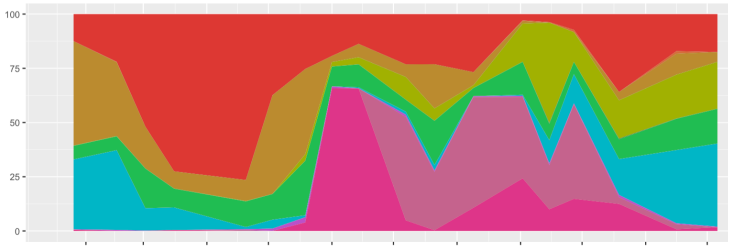
Statistical modeling

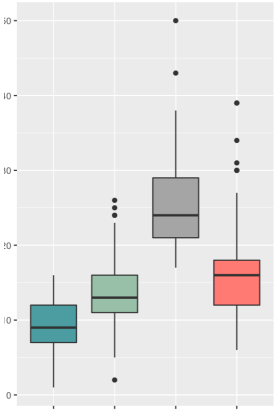
Machine learning

Graphics and visualisation

Static graphics

Cartography

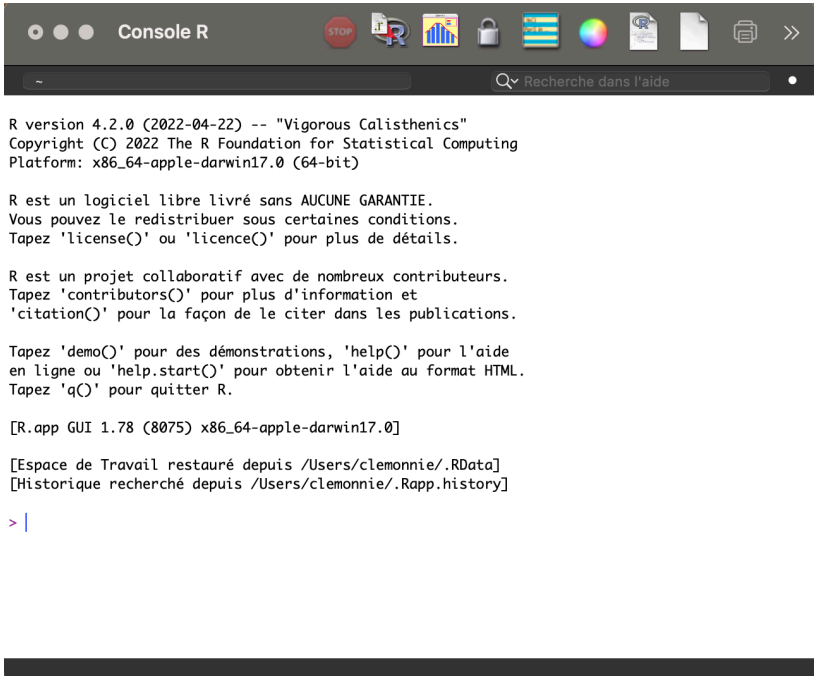




```
Call:
lm(formula = y ~ ., data = data)

Residuals:
    Min      1Q  Median
-8.7859 -2.0085  0.00[illegible]  9.7121

Coefficients:
            Estimat[illegible]  Error [illegible]
(Intercept)  1.3831[illegible]  .24566 [illegible]
x1           5.2977[illegible]  12483 [illegible]
x2           1.61055[illegible]  [illegible]518 [illegible]
x3           0.44947[illegible]  [illegible] [illegible]
groupB       1.87978    0.1[illegible]  [illegible]
---
Signif. codes:  0 ‘***’ 0.001 ‘*[illegible]01 ‘*’ [illegible].’ 0.1 ‘ ’ 1

Residual standard error: 2.817 on 995 degrees of freedom
Multiple R-squared:  0.7882,    Adjusted R-squared:  0.7873
F-statistic: 925.6 on 4 and 995 DF,  p-value: < 2.2e-16
```

R console

R is used through a command line console



```
Call:
lm(formula = y ~ ., data = data)

Residuals:
    Min      1Q  Median
-8.7859 -2.0085  0.00[illegible]  9.7121

Coefficients:
            Estimat[illegible]  Error [illegible]
(Intercept)  1.3831[illegible]  .24566 [illegible] 2.[illegible] [illegible]*
x1           5.2977[illegible]  12483 [illegible] [illegible] [illegible]**
x2           1.61055[illegible]  [illegible]518 [illegible] [illegible]=0[illegible] [illegible]***
x3           0.44947[illegible]  [illegible]19 [illegible]16 [illegible]***
groupB       1.87978  0.16[illegible]  [illegible] [illegible]5 [illegible]***
---
Signif. codes:  0 ‘***’ 0.001 ‘*[illegible]01 ‘*’ [illegible].’ 0.1 ‘ ’ 1

Residual standard error: 2.817 on 995 degrees of freedom
Multiple R-squared:  0.7882,    Adjusted R-squared:  0.7873
F-statistic: 925.6 on 4 and 995 DF,  p-value: < 2.2e-16
```

R console

R is used through a command line console

Set to the working directory

```
> setwd(dir="~/Desktop/R_Introduction/")
```

Load a table

```
> Microscopy_table <- read.table("Microscopy_table.csv", header=T, sep=";")
```

Visualize the table

```
> head(microscopy_table)
```

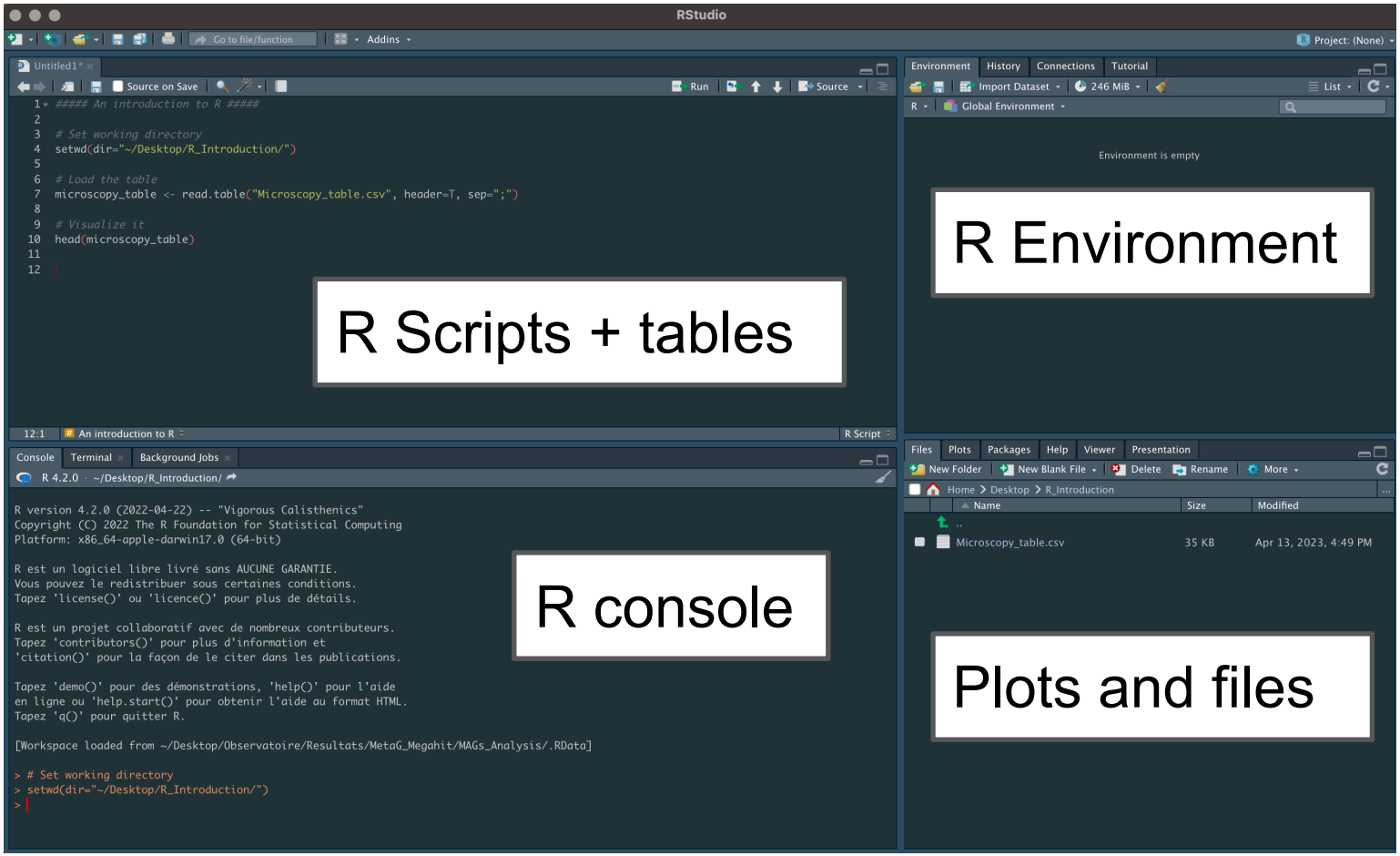
Console R

Recherche dans l'aide

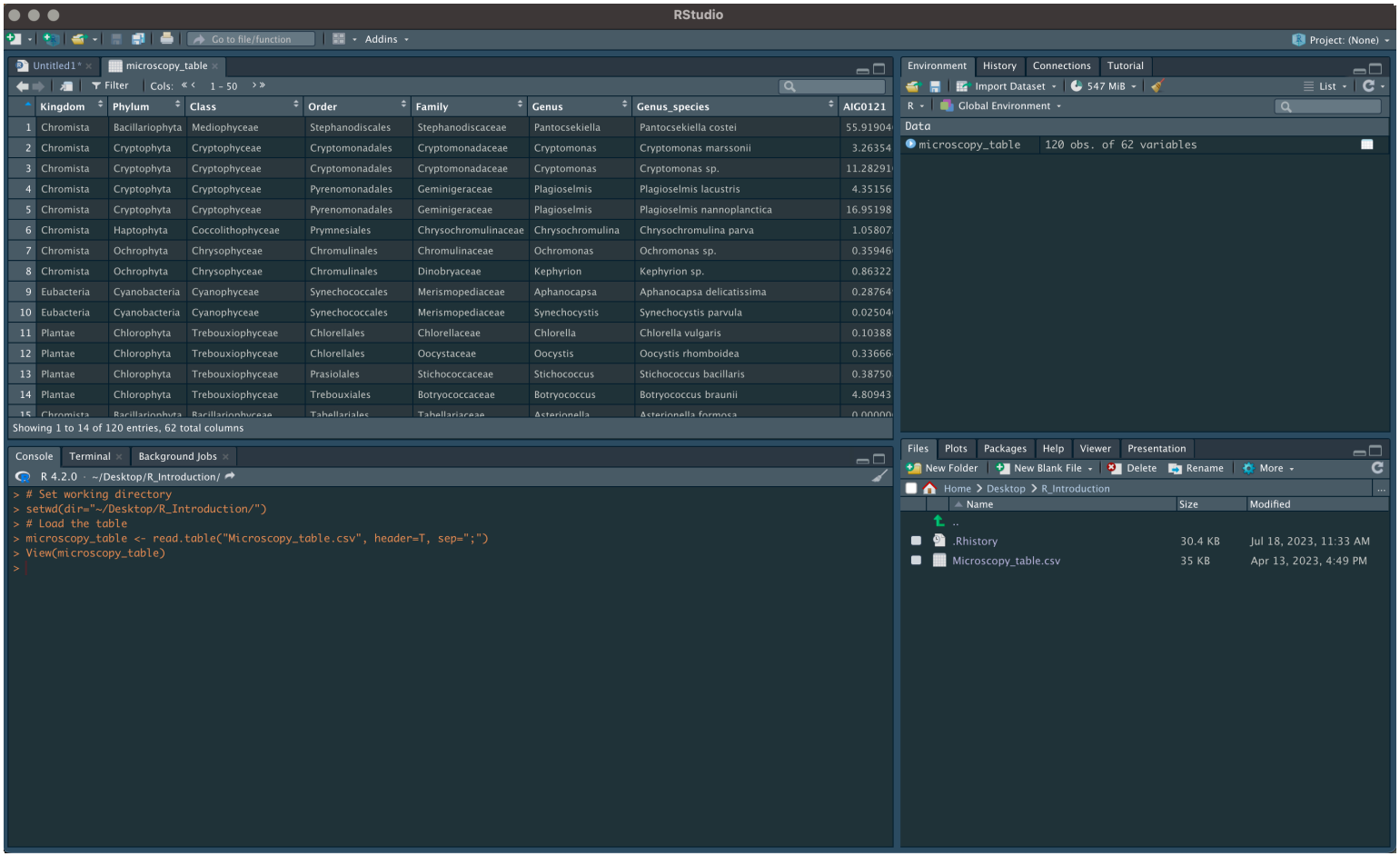
```
> head(microscopy_table)
    Kingdom          Phylum            Class            Order              Family            Genus
1 Chromista Bacillariophyta      Mediophyceae Stephanodiscales    Stephanodiscaceae   Pantocsekiella
2 Chromista     Cryptophyta     Cryptophyceae  Cryptomonadales     Cryptomonadaceae      Cryptomonas
3 Chromista     Cryptophyta     Cryptophyceae  Cryptomonadales     Cryptomonadaceae      Cryptomonas
4 Chromista     Cryptophyta     Cryptophyceae  Pyrenomonadales       Geminigeraceae     Plagioselmis
5 Chromista     Cryptophyta     Cryptophyceae  Pyrenomonadales       Geminigeraceae     Plagioselmis
6 Chromista      Haptophyta Coccolithophyceae     Prymnesiales Chrysochromulinaceae Chrysochromulina
                 Genus_species   AIG0121    AIG0221    AIG0321   AIG0421    AIG0521    AIG0621
1       Pantocsekiella costei 55.919046 83.2014609 99.4668683 96.466437 27.7123437 32.3889979
2       Cryptomonas marssonii  3.263544  1.5293829  0.0000000  1.348493  0.0000000  0.0000000
3            Cryptomonas sp. 11.282910  0.0000000  0.0000000  0.000000  0.0000000  1.0251295
4      Plagioselmis lacustris  4.351567 10.1963147  0.0000000  0.000000  0.8176486  0.0000000
5 Plagioselmis nannoplanctica 16.951986  3.1046142  0.4077566  2.012803  0.5491786  2.3368610
6      Chrysochromulina parva  1.058072  0.1803064  0.0000000  0.000000  0.0000000  0.1573093
    AIG0821    ANN0121    ANN0221     ANN0321  ANN0421    ANN0521    ANN0621    ANN0721     ANN0921
1 4.4191036 31.6921294  6.4354774 32.70982235 21.15961 46.5499520 74.2234603 62.2146306 61.24741155
2 0.0000000  0.0000000  0.0000000  0.00000000  0.00000  0.0000000  0.0000000  0.0000000  0.00000000
3 5.9443496  8.4324278  4.9466674  0.00000000  0.00000  0.0000000  0.0000000  0.0000000  1.12090981
4 0.3275147  7.5884667 42.6079907 40.72716259 25.09137 12.9374044  0.0000000  0.0000000  0.00000000
5 4.6195221  5.8249582 12.2160013  8.89025919 12.80810  6.7198675  2.3360331  4.0361877  2.26483450
6 0.3257769  0.1916999  0.4217108  0.07502195  0.00000  0.1143892  0.3294831  0.0933966  0.02866721
     ANN1021    ANN1121   ANN1221    ANN1321   ANN1421   ANN1521   BOU0121    BOU0221    BOU0321
1 15.6362827 47.8154540 31.351337  7.3038855 2.5921694 0.8209985 22.026309  8.248998 31.5712942
2  0.0000000  0.8207637  0.000000  0.0000000 0.0000000 0.0000000  0.000000  0.000000  0.0000000
3  0.0000000  2.8375975  2.269356 12.4102870 4.3585637 4.4174575 16.692196  2.774031  0.8893837
4  0.6065054  0.7295987  0.000000  0.7977294 0.6724008 0.7572070 14.163176 29.956698  6.1742791
5  2.4441766  1.8131457  1.254102 12.4305409 5.7355972 2.9243484 10.291099 19.042706  3.8705246
6  0.1206577  0.2661004  0.174119  2.2217901 0.5127723 0.1506382  1.109969  1.170627  0.1819710
```

RStudio

Is an integrated development environment (IDE)



RStudio® Is an integrated development environment (IDE)



```
Call:
lm(formula = y ~ ., data = data)

Residuals:
    Min      1Q  Median
-8.7859 -2.0085  0.00
                        9.7121

Coefficients:
            Estimat        Error
(Intercept)  1.3831      .24566
x1           5.29776      12483
x2           1.61055      5518
x3           0.44947      19
groupB       1.87978    0.16
---
Signif. codes:  0 ‘***’ 0.001 ‘*
                01 ‘*’
                ‘.’ 0.1 ‘ ’ 1

Residual standard error: 2.817 on 995 degrees of freedom
Multiple R-squared:  0.7882,    Adjusted R-squared:  0.7873
F-statistic: 925.6 on 4 and 995 DF,  p-value: < 2.2e-16
```

R Language

Command line example

```
> ASV_table <- read.table("ASV_table.txt", header=T, row.names=1, sep="\t")
```

```
Call:
lm(formula = y ~ ., data = data)

Residuals:
    Min      1Q  Median
-8.7859 -2.0085  0.00
                          9.7121

Coefficients:
            Estimat        Error
(Intercept)  1.3831        .24566
x1           5.29776        12483
x2           1.61055        5518
x3           0.44947
groupB       1.87978     0.16
---
Signif. codes:  0 ‘***’ 0.001 ‘*
                                  01 ‘*’
                                        ‘.’ 0.1 ‘ ’ 1

Residual standard error: 2.817 on 995 degrees of freedom
Multiple R-squared:  0.7882,    Adjusted R-squared:  0.7873
F-statistic: 925.6 on 4 and 995 DF,  p-value: < 2.2e-16
```

R Language

Command line example

```
> ASV_table <- read.table("ASV_table.txt", header=T, row.names=1, sep="\t")
```

function

arguments

A function() is made to perform a specific task.

It might works with arguments

```
Call:
lm(formula = y ~ ., data = data)

Residuals:
    Min      1Q  Median
-8.7859 -2.0085  0.00[illegible]  9.7121

Coefficients:
            Estimat[illegible]  Error [illegible]
(Intercept)  1.3831[illegible]  .24566 [illegible]
x1           5.29776[illegible]  12483 [illegible]
x2           1.61055[illegible]  [illegible]518 [illegible]
x3           0.44947[illegible]  [illegible] [illegible]
groupB       1.87978    0.1[illegible]  [illegible]
---
Signif. codes:  0 ‘***’ 0.001 ‘*[illegible]01 ‘*’ [illegible]’ 0.1 ‘ ’ 1

Residual standard error: 2.817 on 995 degrees of freedom
Multiple R-squared:  0.7882,    Adjusted R-squared:  0.7873
F-statistic: 925.6 on 4 and 995 DF,  p-value: < 2.2e-16
```

R Language

Command line example

```
> ASV_table <- read.table("ASV_table.txt", header=T, row.names=1, sep="\t")
```

variable

function

arguments

A variable in R is the memory allocated to the stockage of a specific **object**

It is assigned to an object using either `=` or `<-`

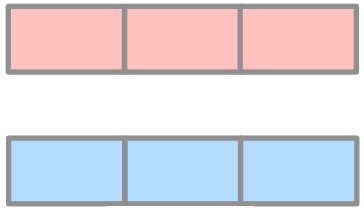
A function() is made to perform a specific task.

It might works with arguments

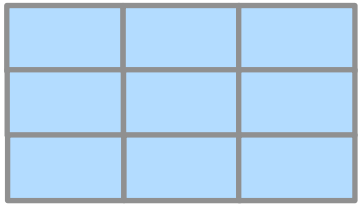
```
Call:
lm(formula = y ~ ., data = data)

Residuals:
    Min      1Q  Median
-8.7859 -2.0085  0.00[illegible]  9.7121

Coefficients:
            Estimat[illegible]  Error [illegible]
(Intercept)  1.3831[illegible]  .24566 [illegible]
x1           5.2977[illegible]  12483 [illegible]
x2           1.61055[illegible]  [illegible]518 [illegible]
x3           0.44947[illegible]  [illegible] [illegible]
groupB       1.87978    0.1[illegible]  [illegible]
---
Signif. codes:  0 ‘***’ 0.001 ‘*[illegible]01 ‘*’ [illegible].’ 0.1 ‘ ’ 1

Residual standard error: 2.817 on 995 degrees of freedom
Multiple R-squared:  0.7882,    Adjusted R-squared:  0.7873
F-statistic: 925.6 on 4 and 995 DF,  p-value: < 2.2e-16
```

R Language

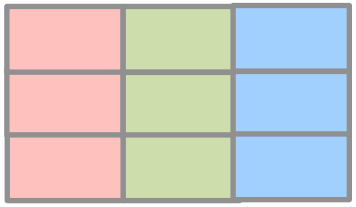
Different type of objects in R



Vector



Matrix



Data frame

```
[1] "Monday"    "Tuesday"
[3] "Wednesday" "Thursday"
[5] "Friday"    "Saturday"
[7] "Sunday"
```

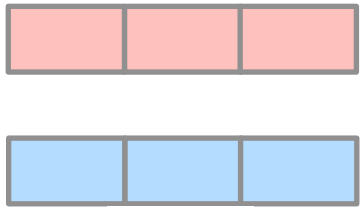
	ANN0121	ANN0221
ASV1	3317	3583
ASV2	1040	359
ASV3	0	9
ASV4	673	509
ASV5	2698	3342

	Month	Date	day
ANN0121	January	19/01/21	19
ANN0221	February	09/02/21	40
ANN0321	March	09/03/21	68
ANN0421	April	01/04/21	91
ANN0521	April	15/04/21	105

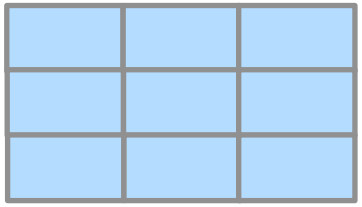
```
Call:
lm(formula = y ~ ., data = data)

Residuals:
    Min      1Q  Median
-8.7859 -2.0085  0.00
                                9.7121

Coefficients:
            Estimat        Error
(Intercept)  1.3831        .24566
x1           5.29776       12483
x2           1.61055       518
x3           0.44947       19
groupB       1.87978     0.16
---
Signif. codes:  0 ‘***’ 0.001 ‘*
                                01 ‘*’
                                .’ 0.1 ‘ ’ 1

Residual standard error: 2.817 on 995 degrees of freedom
Multiple R-squared:  0.7882,    Adjusted R-squared:  0.7873
F-statistic: 925.6 on 4 and 995 DF,  p-value: < 2.2e-16
```

R Language

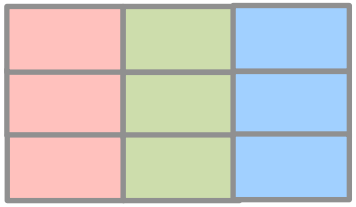
Different type of objects in R



Vector



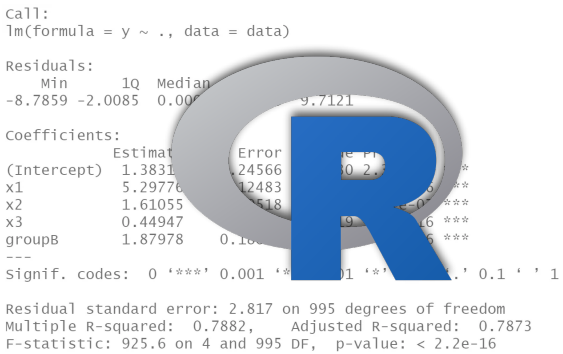
Matrix



Data frame

List
- Vector
- Matrix
- Data frame
- Array

Source: R in Action, p.23



R Language

Different classes of objects in R

Character

« word »

Numeric

« 4.356 »

Integer

« 4 » or « 4L »

Date

« 01/10/2023»

Logical

«TRUE» «FALSE»

Get the class of the object A

class(A)

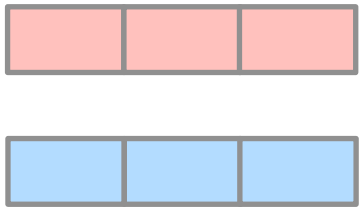
Change A to a specific class

as.numeric(A)

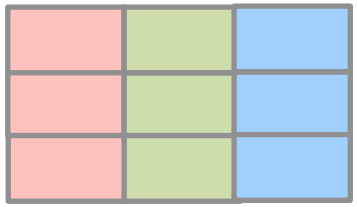
```
Call:
lm(formula = y ~ ., data = data)

Residuals:
    Min      1Q  Median
-8.7859 -2.0085  0.00
                      9.7121

Coefficients:
            Estimat      Error
(Intercept)  1.3831     .24566
x1           5.29776     12483
x2           1.61055     5518
x3           0.44947
groupB       1.87978     0.16
---
Signif. codes:  0 ‘***’ 0.001 ‘*
                                  .’ 0.1 ‘ ’ 1

Residual standard error: 2.817 on 995 degrees of freedom
Multiple R-squared:  0.7882,    Adjusted R-squared:  0.7873
F-statistic: 925.6 on 4 and 995 DF,  p-value: < 2.2e-16
```

R Language

Create objects



Vector



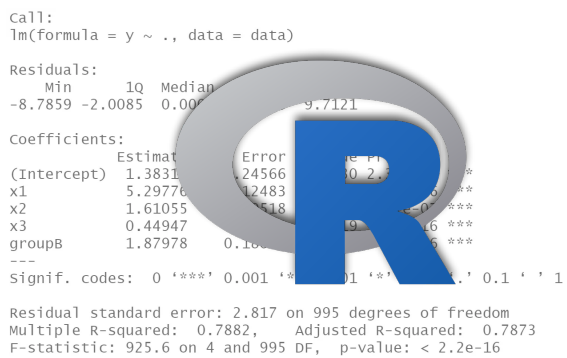
Data frame

List
- Vector
- Matrix
- Data frame
- Array

vec1 <- **c(**« » , « » , « » **)**

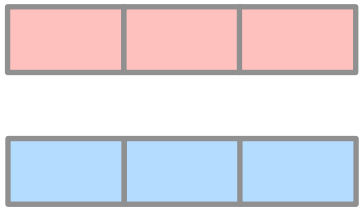
df <- **data.frame**(col1, col2)

list1 <- **list**(vec1, df)

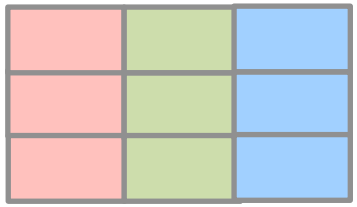


R Language

Manipulate objects using « [ ] »



Vector



Data frame

List
- Vector
- Matrix
- Data frame
- Array

Vec1[2]

Vec1[c(1,3)]

df[, c(2,3)]

rows

column

df$col1

list1[[2]][,c(1:10)]

Object number

Inside object

```
Call:
lm(formula = y ~ ., data = data)

Residuals:
    Min      1Q  Median
-8.7859 -2.0085  0.00
                          9.7121

Coefficients:
            Estimat        Error
(Intercept)  1.3831       .24566
x1           5.29776      12483
x2           1.61055      5518
x3           0.44947
groupB       1.87978     0.16
---
Signif. codes:  0 ‘***’ 0.001 ‘*
                                  01 ‘*’
                                  .’ 0.1 ‘ ’ 1

Residual standard error: 2.817 on 995 degrees of freedom
Multiple R-squared:  0.7882,    Adjusted R-squared:  0.7873
F-statistic: 925.6 on 4 and 995 DF,  p-value: < 2.2e-16
```

R Language

Basic operations and functions

Different operators

R operators	
+	Addition
*	Multiplication
/	Division
-	Soustraction

Relational operators	
>	More than
<	Less than
>=	More or equal
!=	Not equal to

Logical operators	
&	And
|	Or
!	Not

Miscellaneous oper.	
%in%	in

To do a specific mathematical or logical operation

Different functions

subset()
sort()
order()
factor()
str()
print()
plot()
merge()
na.omit()
…

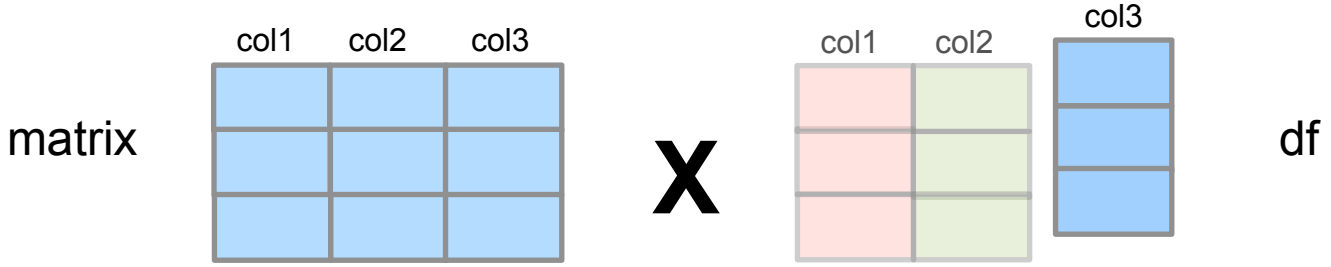
To do a specific task

```
Call:
lm(formula = y ~ ., data = data)

Residuals:
    Min      1Q  Median
-8.7859 -2.0085  0.00
                          9.7121

Coefficients:
            Estimat        Error
(Intercept)  1.3831        .24566
x1           5.29776        12483
x2           1.61055        5518
x3           0.44947
groupB       1.87978     0.16
---
Signif. codes:  0 ‘***’ 0.001 ‘*
                                  01 ‘*’
                                  .’ 0.1 ‘ ’ 1

Residual standard error: 2.817 on 995 degrees of freedom
Multiple R-squared:  0.7882,    Adjusted R-squared:  0.7873
F-statistic: 925.6 on 4 and 995 DF,  p-value: < 2.2e-16
```

R Language

Basic operations and functions

Multiply one matrix by one column of a data frame



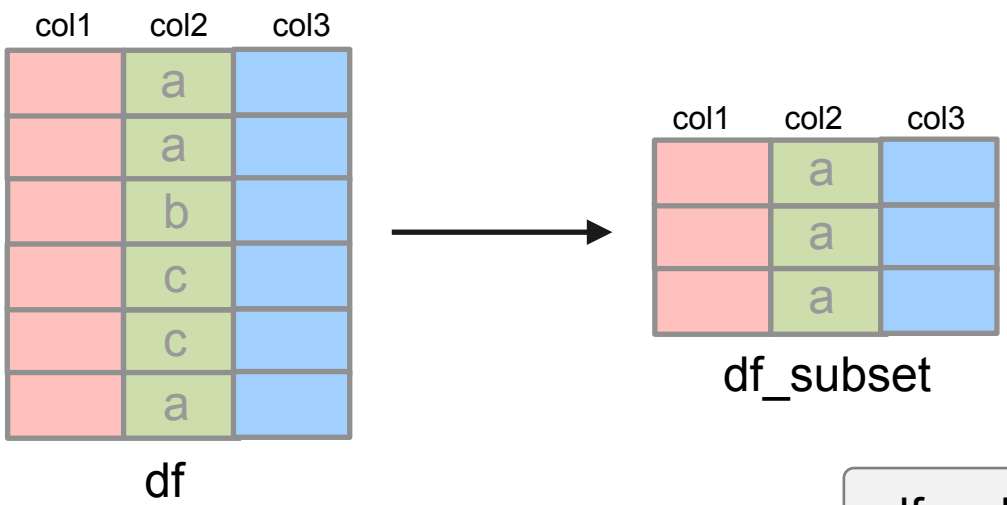

```
new_matrix <- matrix * df$col3
```

```
Call:
lm(formula = y ~ ., data = data)

Residuals:
    Min      1Q  Median
-8.7859 -2.0085  0.00
                                9.7121

Coefficients:
            Estimat        Error
(Intercept)  1.3831        .24566
x1           5.29776       12483
x2           1.61055       5518
x3           0.44947
groupB       1.87978     0.16
---
Signif. codes:  0 ‘***’ 0.001 ‘*
                                  01 ‘*’
                                  .’ 0.1 ‘ ’ 1

Residual standard error: 2.817 on 995 degrees of freedom
Multiple R-squared:  0.7882,    Adjusted R-squared:  0.7873
F-statistic: 925.6 on 4 and 995 DF,  p-value: < 2.2e-16
```

R Language

Basic operations and functions

Keep only rows that are in category « a »




```
df_subset <- subset(df, col2 == « a »)
```

```
Call:
lm(formula = y ~ ., data = data)

Residuals:
    Min      1Q  Median
-8.7859 -2.0085  0.00[illegible]  9.7121

Coefficients:
            Estimat[illegible]  Error [illegible]
(Intercept)  1.3831[illegible]  .24566 [illegible]
x1           5.2977[illegible]  12483 [illegible]
x2           1.61055[illegible]  [illegible]518 [illegible]
x3           0.44947[illegible]  [illegible] [illegible]
groupB       1.87978    0.1[illegible]
---
Signif. codes:  0 ‘***’ 0.001 ‘*[illegible]01 ‘*’ [illegible]’ 0.1 ‘ ’ 1

Residual standard error: 2.817 on 995 degrees of freedom
Multiple R-squared:  0.7882,    Adjusted R-squared:  0.7873
F-statistic: 925.6 on 4 and 995 DF,  p-value: < 2.2e-16
```

R Packages

Combination of different functions for a specific purpose

Most of the time they are available in CRAN

CRAN
The Comprehensive R Archive Network

But sometimes (particularly if they are recent) you can directly install them from Bioconductor or Github

Bioconductor
OPEN SOURCE SOFTWARE FOR BIOINFORMATICS

```
Call:
lm(formula = y ~ ., data = data)

Residuals:
    Min      1Q  Median
-8.7859 -2.0085  0.00[illegible]  9.7121

Coefficients:
            Estimat[illegible]  Error [illegible]
(Intercept)  1.3831[illegible]  .24566 [illegible]
x1           5.29776[illegible]  12483 [illegible]
x2           1.61055[illegible]  [illegible]518 [illegible]
x3           0.44947[illegible]  [illegible]19 [illegible]
groupB       1.87978    0.16[illegible]
---
Signif. codes:  0 ‘***’ 0.001 ‘*[illegible]01 ‘*’ [illegible]’ 0.1 ‘ ’ 1

Residual standard error: 2.817 on 995 degrees of freedom
Multiple R-squared:  0.7882,    Adjusted R-squared:  0.7873
F-statistic: 925.6 on 4 and 995 DF,  p-value: < 2.2e-16
```

R Packages

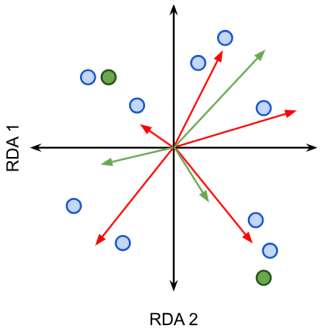
Community ecology : vegan package / ade4 package

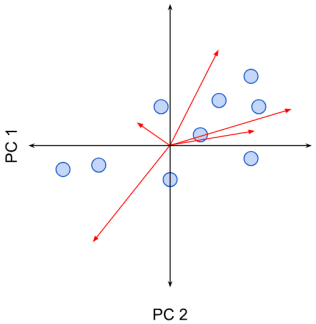
Test hypothesis

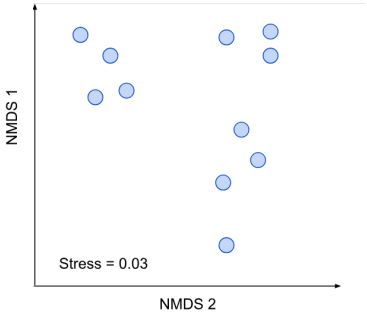
Multivariate analysis

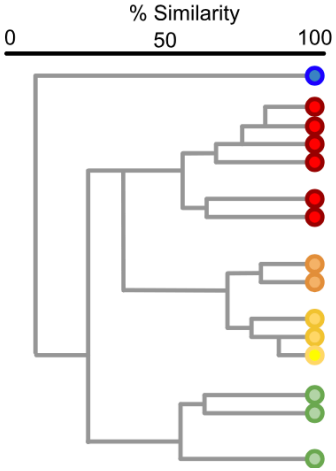
Constrained analysis

Composant analysis, PCA





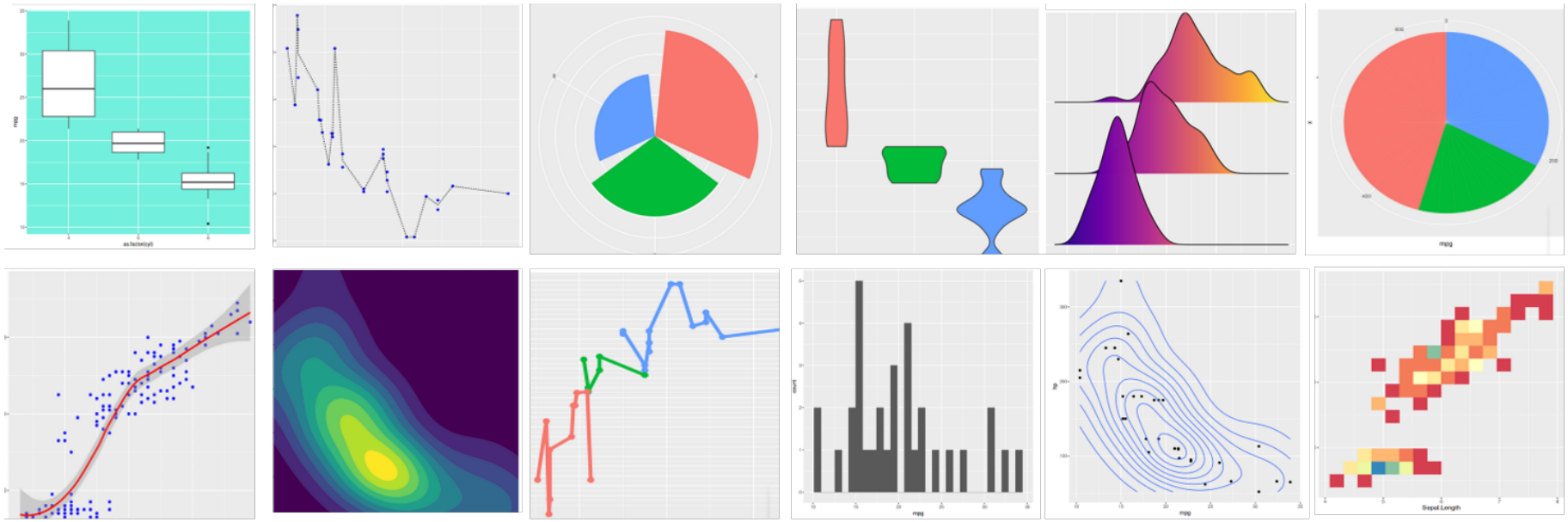




```
Call:
lm(formula = y ~ ., data = data)

Residuals:
    Min      1Q  Median
-8.7859 -2.0085  0.00
                                9.7121

Coefficients:
            Estimat        Error
(Intercept)  1.3831        .24566
x1           5.29776       12483
x2           1.61055       5518
x3           0.44947       19
groupB       1.87978     0.16
---
Signif. codes:  0 ‘***’ 0.001 ‘*
                                01 ‘*’
                                .’ 0.1 ‘ ’ 1

Residual standard error: 2.817 on 995 degrees of freedom
Multiple R-squared:  0.7882,    Adjusted R-squared:  0.7873
F-statistic: 925.6 on 4 and 995 DF,  p-value: < 2.2e-16
```

R Packages

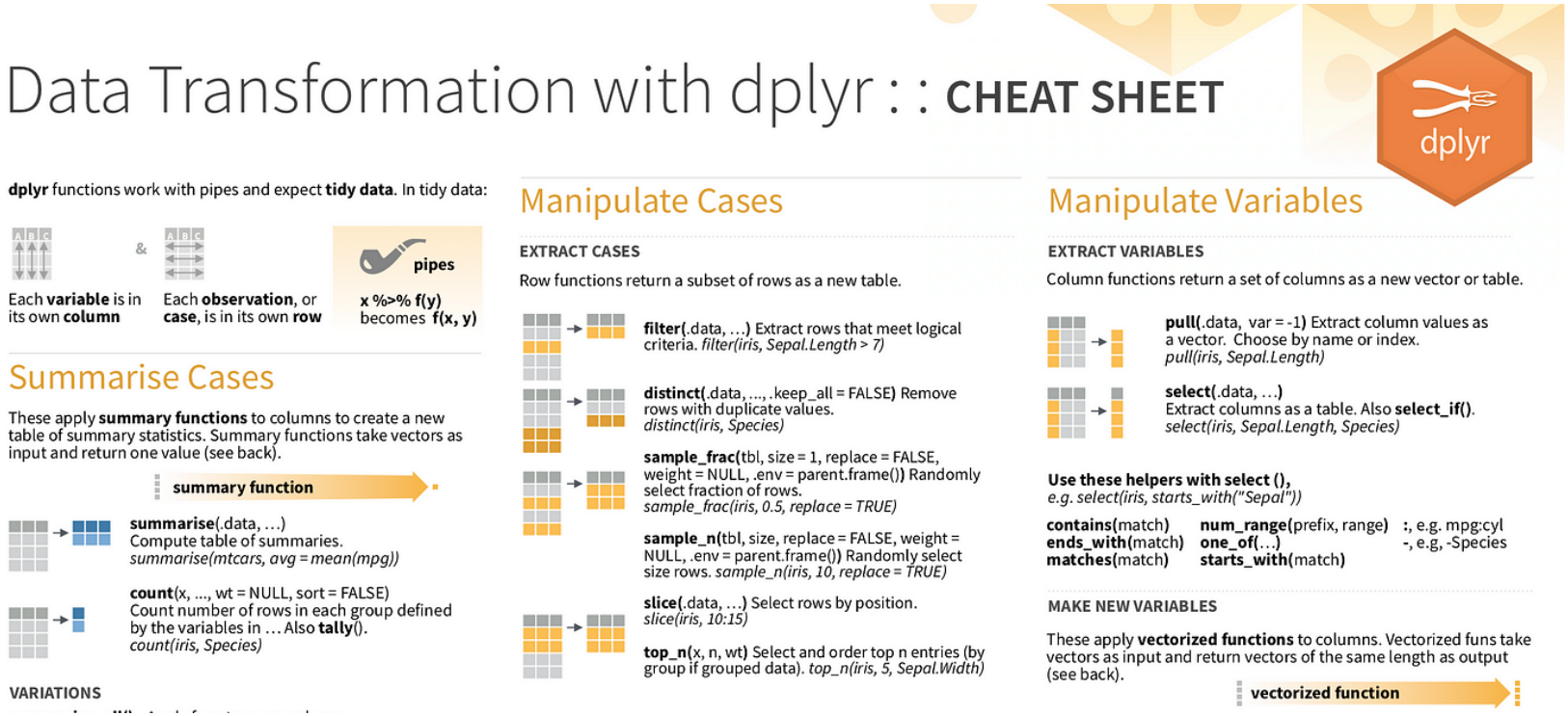
Graphic display : ggplot2



```
Call:
lm(formula = y ~ ., data = data)

Residuals:
    Min      1Q  Median
-8.7859 -2.0085  0.00
                                9.7121

Coefficients:
            Estimat          Error
(Intercept)  1.3831          .24566
x1           5.29776         12483
x2           1.61055         5518
x3           0.44947
groupB       1.87978     0.16
---
Signif. codes:  0 ‘***’ 0.001 ‘*
                                  01 ‘*’
                                  .’ 0.1 ‘ ’ 1

Residual standard error: 2.817 on 995 degrees of freedom
Multiple R-squared:  0.7882,    Adjusted R-squared:  0.7873
F-statistic: 925.6 on 4 and 995 DF,  p-value: < 2.2e-16
```

R Packages

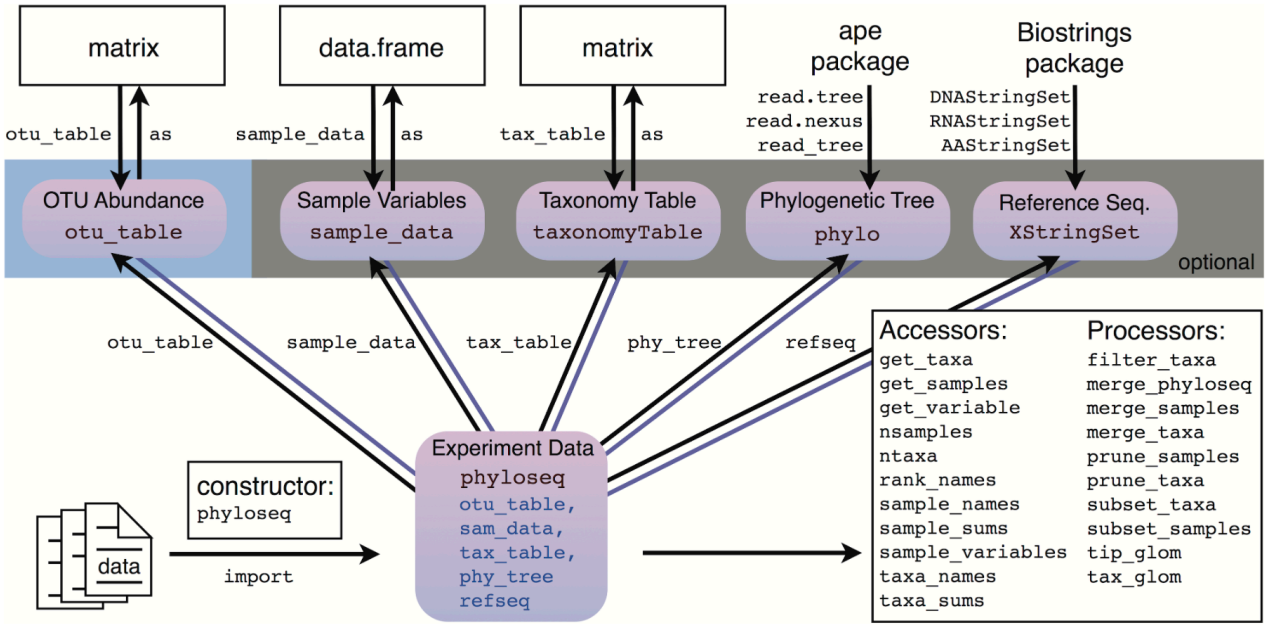
Data manipulation : Dplyr



```
Call:
lm(formula = y ~ ., data = data)

Residuals:
    Min      1Q  Median
-8.7859 -2.0085  0.00
                     9.7121

Coefficients:
            Estimat      Error
(Intercept)  1.3831     .24566
x1           5.2977     12483
x2           1.61055     518
x3           0.44947
groupB       1.87978    0.16
---
Signif. codes:  0 '***' 0.001 '*
                                  '.' 0.1 ' ' 1

Residual standard error: 2.817 on 995 degrees of freedom
Multiple R-squared:  0.7882,    Adjusted R-squared:  0.7873
F-statistic: 925.6 on 4 and 995 DF,  p-value: < 2.2e-16
```

R Packages

A package for metabarcoding data analysis : phyloseq



```
Call:
lm(formula = y ~ ., data = data)

Residuals:
    Min      1Q  Median
-8.7859 -2.0085  0.00[illegible]  9.7121

Coefficients:
            Estimat[illegible]  Error [illegible]
(Intercept)  1.3831[illegible]  .24566 [illegible]
x1           5.29776[illegible]  12483 [illegible]
x2           1.61055[illegible]  5518 [illegible]
x3           0.44947[illegible]  [illegible]
groupB       1.87978    0.16[illegible]
---
Signif. codes:  0 ‘***’ 0.001 ‘*[illegible]01 ‘*’ [illegible].’ 0.1 ‘ ’ 1

Residual standard error: 2.817 on 995 degrees of freedom
Multiple R-squared:  0.7882,    Adjusted R-squared:  0.7873
F-statistic: 925.6 on 4 and 995 DF,  p-value: < 2.2e-16
```

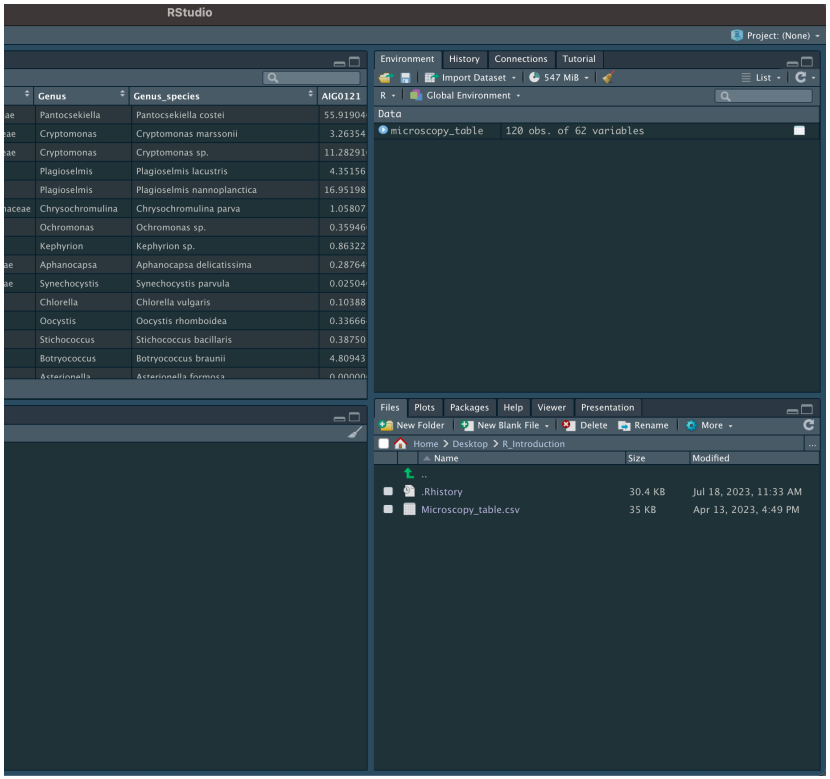
R Help

Learning how to code in R language could be the subject of an entire workshop

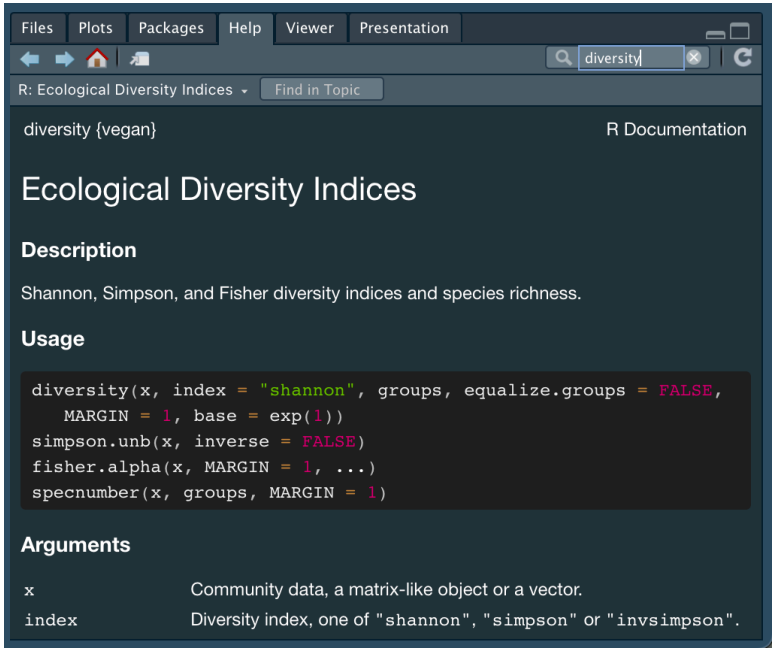
It takes time to understand how the R function works, how to have the good code that will do what we want…

An important reflex : search for help

```
Call:
lm(formula = y ~ ., data = data)

Residuals:
    Min      1Q  Median
-8.7859 -2.0085  0.00[illegible]  9.7121

Coefficients:
            Estimat[illegible]  Error [illegible]
(Intercept)  1.3831[illegible]  .24566 [illegible]
x1           5.2977[illegible]  12483 [illegible]
x2           1.61055[illegible]  [illegible]518 [illegible]
x3           0.44947[illegible]  [illegible] [illegible]
groupB       1.87978  0.1[illegible]  [illegible]
---
Signif. codes:  0 ‘***’ 0.001 ‘*[illegible]01 ‘*’ [illegible]’ 0.1 ‘ ’ 1

Residual standard error: 2.817 on 995 degrees of freedom
Multiple R-squared:  0.7882,    Adjusted R-squared:  0.7873
F-statistic: 925.6 on 4 and 995 DF,  p-value: < 2.2e-16
```



R Help



```
Call:
lm(formula = y ~ ., data = data)

Residuals:
    Min      1Q  Median
-8.7859 -2.0085  0.00
                        9.7121

Coefficients:
            Estimat        Error
(Intercept)  1.3831      .24566
x1           5.29776      12483
x2           1.61055      518
x3           0.44947
groupB       1.87978     0.16
---
Signif. codes:  0 '***' 0.001 '*
                                  01 '*'
                                          .' 0.1 ' ' 1

Residual standard error: 2.817 on 995 degrees of freedom
Multiple R-squared:  0.7882,    Adjusted R-squared:  0.7873
F-statistic: 925.6 on 4 and 995 DF,  p-value: < 2.2e-16
```

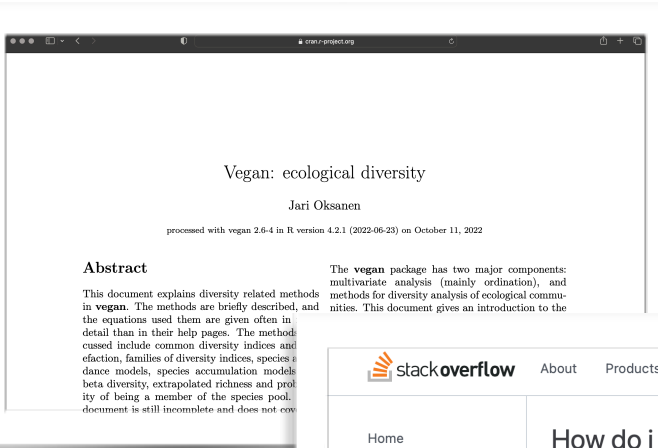
R Help

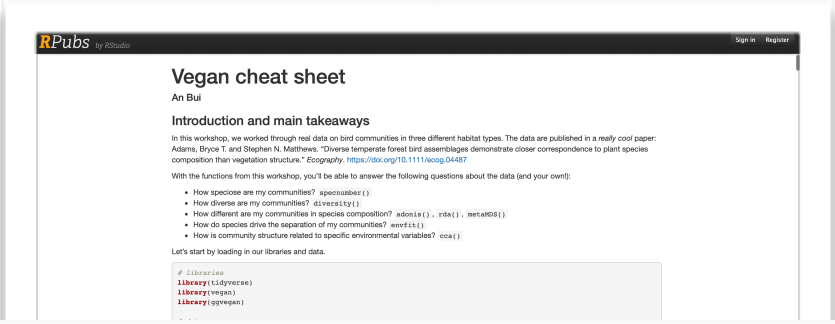
Any question has an answer on internet !!

Official documentation of Vegan package

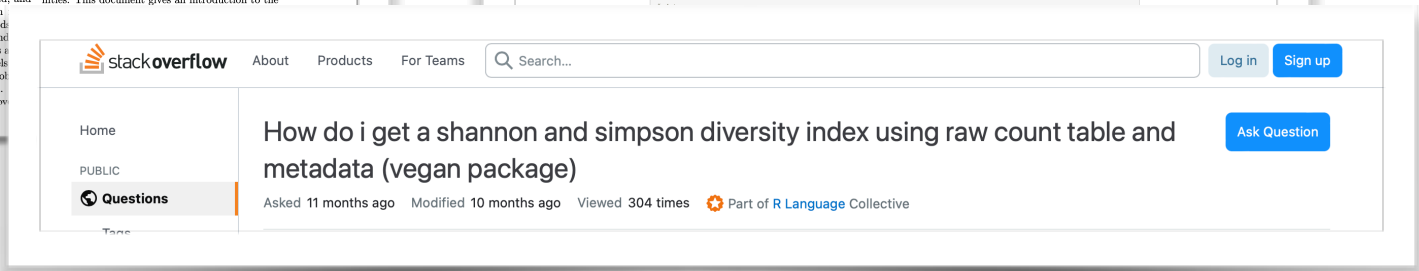
Calculate Shannon diversity index vegan r

Tutorial made by other scientists





Forums



Now let’s practice !